Restoration Plan
for the
Northwest Fork of the Loxahatchee River

South Florida Water Management District
Watershed Management Department
Coastal Ecosystems Division

Final Draft
Part 2
List of Acronyms, Glossary and Appendices
February 8, 2006

ACRONYMS AND ABBREVIATIONS

^{o}C or C	degrees in Centigrade
^{o}F	degrees in Fahrenheit
ADCP	acoustic doppler current profiler
ASCE	American Society of Civil Engineers
BD	Boy Scout Dock station
bls	below land surface
BOD	biological oxygen demand
BWP	box and wisker plot
CERP	Comprehensive Everglades Restoration Plan
cfs	cubic feet per second
CG	U.S. Coast Guard station
CH3D	3-D model that simulates supercritical flows
cm	centimeter
CSFFCP	Central and Southern Florida Flood Control Project
CUP	Consumptive Use Permitting
Db	mean number of days between salinity events
dbh	diameter at breast height (tree measurement)
DBHydro	SFWMD's corporate environmental database
District	South Florida Water Management District
Ds	mean duration in days of salinity event
Ds/Db	calculated salinity ratio
E	Endangered species
ET	evapotranspiration
F.A.C.	Florida Administrative Code
FCREPA	Florida Committee on Rare and Endangered Plants and Animals
FDA	Florida Department of Agriculture
FDEP	Florida Department of Environmental Protection
FDNR	Florida Department of Natural Resources (now FDEP)
FFWCC	Florida Fish and Wildlife Conservation Commission (now FWC)
FGFWFC	Florida Game and Fresh Water Fish Commission
FNAI	Florida Natural Areas Inventory

FPS	Florida Park Service, a division of FDEP
ft	feet
F.S.	Florida Statutes
FWC	Florida Fish and Wildlife Conservation Commission
FWF	Florida Wildlife Federation
FWQI	Florida Water Quality Index
FWRI	Fish and Wildlife Research Institute
GIS	geographic information system
GPS	global positioning system
GUI	Graphic user interface
H^0	null hypothesis
HSPF	Hydrologic Simulation Program – FORTRAN
Hz	hertz
ICW	Intracoastal Waterway
in	inches
IRL	Indian River Lagoon
JDSP	Jonathan Dickinson State Park
JID	Jupiter Inlet District
KC	Kitching Creek station
KHz	Kilohertz
km	kilometers
LEC Plan	Lower East Coast Regional Water Supply Plan
LECsR	Lower East Coast Subregional Model
LIDAR	LIght Detection And Ranging
LOSM	Loxahatchee Oyster Stress Model
LRD	Loxahatchee River Environmental Control District
LRPI	Loxahatchee River Preservation Initiative
LSMM	Long-term Salinity Management Model
LSUR	Length-scale parameter for surface drainage
LSZ	low salinity zone
LT	lower tidal reach
LU	land use
LZS	lower zone storage
m	meters

MAP	Monitoring and Assessment Program
MFL	minimum flow and level
MGD or mgd	million gallons per day
mg/L	milligrams per liter
mm	millimeters
MOA	Memorandum of Agreement
MOU	Memorandum of Understanding
NA	not applicable or not available
NAVD	North American Vertical Datum
NFSP	Northwest Fork Science Plan
NGVD	National Geodetic Vertical Datum
NMFS	National Marine Fisheries Service
NOAA	National Ocean and Atmospheric Administration
Northern Plan	North Beach Palm County Comprehensive Water Management Plan
NPBC	North Palm Beach County
NPS	National Park System
PD	Pompano Drive station
P.L.	Public Law
PLRGs	Pollution Load Reduction Goals
PM	performance measure
POR	Period of Record
ppb	parts per billion
ppt	parts per thousand
PT	pretreatment score
R	riverine reach
RBA	relative basal area
RECOVER	REstoration COordination VERification
RM	river mile
RMA-2/RMA-4	2-D hydrodynamic and salinity models developed by Resource Management Associates, Inc.
RMS	root mean square
RRE	relative RMS error
SAVELOX	SAlinity and VEgetation model for the LOXahatchee
SCADA	Supervisory Control and Data Acquisition

SFWMD	South Florida Water Management District
SFWMM	South Florida Water Management Model
SIRWCD	South Indian River Water Control District
SJRWMD	St. Johns River Water Management District
sp.	species
sq.	square
S.R.	State Road
SSC	species of special concern
STA	stormwater treatment area
T	Threatened
TBD	to be determined
TMDL	total maximum daily load
TN	total nitrogen
TP	total phosphorus
TSI	Florida Trophic State Index
UCF	University of Central Florida
U.S.	United States
USACE	United States Army Corps of Engineers
USDC	United States Department of Commerce
USDOI	United States Department of Interior
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
UT	upper tidal reach
UZS	upper zone storage
VEC	valued ecosystem component
WaSh	Watershed Model
WRAP	Wetland Rapid Assessment Procedures
WSE	Water Supply and Environmental

GLOSSARY

1995 Base Case A model simulation, which provides an understanding of the how the 1995 water management system with 1995 land use and demands responds to historic (1965-1995) climatic conditions.

1-in-10 Year Drought A drought of such intensity, that it is expected to have a return frequency of once in ten years. A drought, in which below normal rainfall, has a 90 percent probability of being exceeded over a twelve-month period. This means that there is only a 10 percent chance that less than this amount of rain will fall in any given year.

1-in-10 Year Level of Certainty Probability that the needs for reasonable-beneficial uses of water will be fully met during a 1-in-10 year drought.

2020 Base Case A model simulation which provides information of how the 1995 water management system would respond to anticipated future operations and demands under historic (1965-1995) climatic conditions with currently authorized restoration projects implemented, but without Restudy features.

Achievable Restoration Goal The level of restoration can be achieved given the physical, structural, ecological (and cultural) constraints of the system.

Acre-foot The volume of water that covers one acre to a depth of one foot; 43,560 cubic feet; 1,233.5 cubic meters; 325,872 gallons.

Anthropogenic Resulting from human influence.

Aquatic Preserve Water bodies that are set aside by the state to be maintained in essentially natural or existing condition, for protection of fish and wildlife and public recreation so that their aesthetic biological and scientific values may endure for the enjoyment of future generations.

Aquifer A portion of a geologic formation or formations that yield water in sufficient quantities to be a supply source.

Aquifer System A heterogeneous body of intercalated permeable and less permeable material that acts as a water-yielding hydraulic unit of regional extent.

Available Supply The maximum amount of reliable water supply including surface water, groundwater and purchases under secure contracts.

Average Daily Demand A water system's average daily use based on total annual water production (total annual gallons or cubic feet divided by 365).

Average Rainfall Year A year having rainfall with a 50 percent probability of being exceeded over a twelve-month period.

Baseline Condition (see *Reference Condition*)

Baseline Period A specified period of time during which collected data are used for comparisons with subsequent data.

Basin (Surface Water) A tract of land drained by a surface water body or its tributaries.

Bathymetry The measurement of water depth at various places in a body of water.

Benthic Pertaining to the bottom or sediment habitats of a body of water.

Benthos/Benthic Macroscopic organisms that live on or in the bottom substrate, such as clams and worms (contrast to plankton and nekton).

Biological Oxygen Demand (BOD) The amount of dissolved oxygen required to meet the metabolic needs of aerobic microorganisms in water rich in organic matter, such as sewage. Also known as Biochemical Oxygen Demand.

Biomass The amount of living material in a particular sample, population, area or volume of habitat, usually measured as dry mass.

Bioturbation The recycling of nutrients from lake sediments to the overlying water column caused by the burrowing and feeding activities of benthic invertebrates and fish.

Brackish Water with a chloride level greater than 250 mg/L and less than 19,000 mg/L.

Central and Southern Florida Flood Control Project (C&SF Project) A complete system of canals, storage areas and water control structures spanning the area from Lake Okeechobee to both the east and west coasts and from Orlando south to the Everglades. It was designed and constructed during the 1950s by the United States Army Corps of Engineers (USACE) to provide flood control and improve navigation and recreation.

Chironomids Any of a family (Chironomidae) of midges that lack piercing mouthparts.

Class I through V Surface Water Quality Standards As defined by Chapter 62-302.400, F.A.C., all surface waters in Florida have been classified according to designated use as follows:

Class I	Potable water supplies
Class II	Shellfish propagation or harvesting

Class III Recreation, propagation and maintenance of a healthy, well-balanced population of fish and wildlife

Class IV Agricultural water supplies

Class V Navigation, utility and industrial use

Comprehensive Everglades Restoration Plan (CERP) The framework and guide for the restoration, protection and preservation of the south Florida ecosystem. The CERP also provides for water-related needs of the region, such as water supply and flood protection.

Consumptive Use Use that reduces an amount of water in the source from which it is withdrawn.

Consumptive Use Permitting (CUP) The issuance of permits by the SFWMD, under authority of Chapter 40E-2, F.A.C., allowing withdrawal of water for consumptive use.

Control Structure A man-made structure designed to regulate the level/flow of water in a canal or water body (e.g., weirs, dams).

Critical Water Supply Problem Areas (see *Water Resource Caution Areas*)

Decomposition The action of microorganisms breaking down organic compounds into simpler ones, resulting in the release of energy.

Demand The quantity of water needed to be withdrawn to fulfill a requirement.

Demographic Relating to population or socioeconomic conditions.

Denitrification Reduction of nitrates or nitrites commonly by bacteria (as in soil) that usually results in the escape of nitrogen into the air.

Diatom Any of a class (Bacillariophyceae) of minute planktonic unicellular or colonial algae with silicified skeletons.

Discharge The rate of water movement past a reference point, measured as volume per unit time (usually expressed as cubic feet or cubic meters per second).

Dissolved Oxygen - The concentration of oxygen dissolved in water, sometimes expressed as percent saturation, where saturation is the maximum amount of oxygen that theoretically can be dissolved in water at a given altitude and temperature.

District Water Management Plan (DWMP) Regional water resource plan developed by the District under Ch. 373.036, F. S.

Districtwide Water Supply Assessment (DWSA) Document providing water demand assessments, projections and descriptions of the surface water and groundwater resources within each of the SFWMD's four planning areas.

Domestic Self-Supplied (DSS) Water Demand (*Same as Residential Self-Supplied Water Demand*) The water used by households whose primary source of water is private wells and water treatment facilities with pumpages of less than 0.10 million gallons per day.

Domestic Use Use of water for household purposes of drinking, bathing, cooking or sanitation.

Drainage District A locally constituted drainage, water management or water control district that is created by special act of the legislature and authorized under Ch. 298 F.S., to constrict, complete, operate, maintain, repair and replace any and all works necessary to implement an adopted water control plan.

Drawdown The vertical distance a water level is lowered resulting from a withdrawal at a given point.

Drought A long period of abnormally low rainfall, especially one that adversely affects growing or living conditions.

Ecosystem Biological communities together with their environment, functioning as a unit.

Effective Rainfall The portion of rainfall that infiltrates the soil and is stored for plant use in the crop root zone, as calculated by the modified Blaney-Criddle model.

Emergent Macrophytes Wetland plants that extend above the water surface. Cattail and rushes are two examples.

Environmental Resource Permit (ERP) A permit issued by the SFWMD under authority of Chapter 40E-4 F.A.C. to ensure that land development projects do not cause adverse environmental, water quality or water quantity impacts.

Ephemeral Surface water that carries or water body that holds water only during and immediately after periods of rainfall.

Epiphytes Plants that derive their moisture and nutrients from the air and rain, usually growing on other plants.

Estuary The part of the wide lower course of a river where its current is met by ocean tides or an arm of the sea at the lower end of a river where fresh and salt water meet.

Eutrophic An aquatic environment enriched with nutrients, usually associated with high plant productivity and low oxygen levels.

Eutrophication The gradual increase in nutrients in a body of water. Natural eutrophication is a gradual process, but human activities may greatly accelerate the process.

Evapotranspiration (ET) Water losses from the surface of water and soils (evaporation) and plants (transpiration).

Everglades Agricultural Area (EAA) An area of histosols (muck) extending south from Lake Okeechobee to the northern levee of WCA-3A, from its eastern boundary at the L-8 Canal to the western boundary along the L-1, L-2 and L-3 levees. The EAA incorporates almost 3,000 square kilometers (1,158 square miles) of highly productive agricultural land.

Everglades Construction Project (ECP) Twelve interrelated construction projects located between Lake Okeechobee and the Everglades. The cornerstone of the ECP is six large constructed wetlands known as Stormwater Treatment Areas (STAs). They use naturally occurring biological processes to reduce phosphorus that enters the Everglades. The ECP also contains four hydropattern restoration projects designed to improve the volume, timing and distribution of water entering the Everglades.

Everglades Protection Area This area is comprised of the Water Conservation Areas and Everglades National Park.

Everglades Stormwater Program A program to ensure that water quality standards are met at all structures not included in the Everglades Construction Project.

Exotic Plant Species A nonnative species that tends to out-compete native species and become quickly established, especially in areas of disturbance or where the normal hydroperiod has been altered.

Fauna All animal life associated with a given habitat.

Fiscal Year (FY) The South Florida Water Management District’s fiscal year begins on October 1 and ends on September 30 the following year.

Flatwoods (Pine) Natural communities that occur on level land and are characterized by a dominant overstory of slash pine. Depending on soil drainage characteristics and position in the landscape, pine flatwoods habitats can exhibit xeric to moderately wet conditions.

Floating Aquatic Vegetation (FAV) Wetland plants that have portions floating at or near the water surface but are rooted in substrate (e.g., water lily).

Flora All plant life associated with a given habitat.

Florida Administrative Code (F.A.C.) The Florida Administrative Code is the official compilation of the administrative rules and regulations of state agencies.

Florida Department of Agricultural and Consumer Services (FDACS) FDACS communicates the needs of the agricultural industry to the Florida Legislature, the FDEP, and the water management districts, and ensures participation of agriculture in the development and implementation of water policy decisions. FDACS also oversees Florida's soil and water conservation districts, which coordinate closely with the federal Natural Resources Conservation Service (NRCS).

Florida Department of Environmental Protection (FDEP) The SFWMD operates under the general supervisory authority of the FDEP, which includes budgetary oversight.

Florida Statutes (F.S.) The Florida Statutes are a permanent collection of state laws organized by subject area into a code made up of titles, chapters, parts and sections. The Florida Statutes are updated annually by laws that create, amend or repeal statutory material.

Florida Water Plan State-level water resource plan developed by the FDEP under Section 373.036 F.S.

Floridan Aquifer System (FAS) A highly-used aquifer system composed of the Upper Floridan and Lower Floridan Aquifers. It is the principal source of water supply north of Lake Okeechobee and the upper Floridan Aquifer is used for drinking water supply in parts of Martin and St. Lucie counties. From Jupiter to south Miami, water from the Floridan Aquifer System is mineralized (total dissolved solids are greater than 1,000 mg/L) along coastal areas and in southern Florida.

Flow The actual amount of water flowing by a particular point over some specified time. In the context of water supply, flow represents the amount of water being treated, moved or reused. Flow is frequently expressed in millions of gallons per day (MGD).

Food Web The totality of interacting food chains in an ecological community.

Geographic Information Systems (GIS) The abstract representation of natural (or cultural) features of a landscape into a digital database, geographic information system.

Governing Board Governing Board of the South Florida Water Management District.

Groundwater Water beneath the soil surface, whether or not flowing through known and definite channels.

Groundwater Heads Elevation of water table.

Harm As defined in Rule 40E-8, F.A.C., the temporary loss of water resource functions that results from a change in surface or groundwater hydrology and takes a period of one to two years of average rainfall conditions to recover.

Hectare A unit of measure in the metric system equal to 10,000 square meters (2.47 acres).

Hydrogeomorphology The scientific study of the physical appearance and operational character of a water body as it adjusts its boundaries to the magnitude of flow and erosional debris produced within the watershed.

Hydrological Alterations The lack of adequate seasonal water level flunctuations and an unnatural reversal of seasonal high and low water levels.

Hydrology The scientific study of the properties, distribution and effects of water on the earth's surface, in the soil and underlying rocks and in the atmosphere.

Hydropattern Water depth, duration, timing and distribution of fresh water in a specified area. A consistent hydropattern is critical for maintaining various ecological communities in wetlands.

Hydroperiod The frequency and duration of inundation or saturation of an ecosystem. In the context of characterizing wetlands, the term hydroperiod describes that length of time during the year that the substrate is either saturated or covered with water.

Hypoxic A deficiency of oxygen reaching the tissues of the body.

Incremental Simulations Model simulations performed to understand how the system would perform with partial completion of the Restudy projects and if the ability to meet the 1-in-10 year level of certainty criteria improves over time. Incremental years selected were, 2005, 2010 and 2015.

Indian River Lagoon Extending for 156 miles from north of Cape Canaveral to Stuart along the east coast of Florida, this lagoon is America’s most diverse estuary, home to more than 4,000 plant and animal species.

Indicator Region A grouping of model grid cells within the SFWMM consisting of similar vegetation cover and soil type. By grouping cells, the uncertainty of evaluating results from a single two by two, square mile grid cell that represents a single water management gage is reduced.

Infiltration The movement of water through the soil surface into the soil under the forces of gravity and capillarity.

Inorganic Involving neither organic life nor the products of organic life; relating to or composed of chemical compounds not containing hydrocarbon groups.

Institute of Food and Agricultural Sciences (IFAS) Agricultural branch of the University of Florida that performs research, education and extension.

Intrusion (see *Saline Water or Saltwater Intrusion*)

Invasive Exotic Species Species of plants or animals that are not naturally found in a region (nonindigenous). They can sometimes aggressively invade habitats and cause multiple ecological changes, including the displacement of native species.

Irrigation The application of water to crops and other plants by artificial means.

Isohaline Zone Transition between the saltier mesohaline and the fresher oligohaline habitats.

Lagoon A body of water separated from the ocean by barrier islands, with limited exchange with the ocean through inlets.

Lake Okeechobee Largest freshwater lake in Florida. Located in central Florida, the lake measures 730 square miles and is the second largest freshwater lake wholly within the United States.

Levee An embankment to prevent flooding or a continuous dike or ridge for confining the irrigation areas of land to be flooded.

Level of Certainty Probability that the demands for reasonable-beneficial uses of water will be fully met for a specified period of time (generally taken to be one year) and for a specified condition of water availability (generally taken to be a drought event of a specified return frequency). For preparing regional water supply plans, the goal associated with identifying the water supply demands of existing and future reasonable beneficial uses is based on meeting those demands for a drought event with a 1-in-10 year return frequency.

Limnology The scientific study of bodies of fresh water for their biological, physical and geological properties.

Littoral Of, relating to, situated or growing on or near a shore.

Load Concentration times flow.

Macrophytes Visible (non-microscopic) plants found in aquatic environments. Examples in south Florida wetlands include sawgrass, cattail, sedges and lilies.

Marsh A frequently or continually inundated non-forested wetland characterized by emergent herbaceous vegetation adapted to saturated soil conditions.

Mesocosm An experimental approach to quantify the responses of a whole plant and animal community.

Mesohaline Term to characterize waters with salinity of 5 to 18 parts per thousand, due to ocean-derived salts.

Microorganism A microscopic organism, including bacteria, protozoans, yeast, viruses and algae.

Minimum Flow and Level (MFL) The point at which further withdrawals would cause significant harm to the water resources.

Muck Dark, organic soil derived from well-decomposed plant biomass.

National Geodetic Vertical Datum (NGVD) A nationally established reference for elevation data.

Natural Resources Conservation Service (NRCS) An agency of the U.S. Department of Agriculture (USDA) that provides technical assistance for soil and water conservation, natural resource surveys and community resource protection. Formerly the U.S. Soil Conservation Service (SCS).

Nekton Macroscopic organisms swimming actively in water, such as fish (contrast to plankton).

Nitrification The oxidation (as by bacteria) of ammonium salts to nitrites and the further oxidation of nitrites to nitrates.

Nitrogen Fixation The metabolic assimilation of atmospheric nitrogen into ammonia by soil microorganisms and especially rhizobia.

Nonpoint source Source originating over broad areas, such as areas of fertilizer and pesticide application or leaking sewer systems, rather than from discrete points.

North American Vertical Datum (NAVD) The official civilian vertical control datum (reference for elevation data) for surveying and mapping activities in the United States.

Nutrient Cycle The cyclic conversions of nutrients from one form to another within the biological communities. A simple example of such a cycle would be the production and release of molecular oxygen (O_2) from water (H_2O) during photosynthesis by plants and the subsequent reduction of atmospheric oxygen to water by the respiratory metabolism of other biota. The cycle of nitrogen is much more complex, with the nitrogen atom undergoing several changes in oxidation state (N_2, NO_3-, R-NH_2 and NH_4, among others) during the cycling of this element through the biological community, and into the air, water or soil and back.

Nutrients Organic or inorganic compounds essential for the survival of an organism. In aquatic environments, nitrogen and phosphorus are important nutrients that affect the growth rate of plants.

Oligohaline Term to characterize water with salinity of 0.5 to 5.0 parts per thousand, due to ocean-derived salts.

Oligotrophic An aquatic environment depleted of nutrients, resulting in low plant productivity.

Organics Involving organic or products of organic life; relating to or composed of chemical compounds containing hydrocarbon groups.

Outflow The act or process of flowing out of.

Outstanding Florida Waters (OFW) A special category of water bodies within the state that have been defined by FDEP, based on Section 403.0619270, F.S., to be worthy of special protection because of their natural attributes.

Pelagic Zone Open water zone.

Per Capita Use Total use divided by the total population served.

Periphyton The biological community of microscopic plants and animals attached to surfaces in aquatic environments. Algae are the primary component in these assemblages, which naturally reduce phosphorus levels in water and serve a key function in Stormwater Treatment Areas.

Performance Measure Performance measures quantify how well or how poorly an alternative meets a specific objective. Good performance measures are quantifiable, have a specific target, indicate when a target has been reached, and measure the degree to which the goal has been met.

Permeability Defines the ability of a substrate to transmit fluid.

Phosphorus (P) An element that is essential for life. In freshwater aquatic environments, phosphorus is often in short supply; increased levels can promote the growth of algae and other plants.

Photosynthesis The process in green plants and certain other organisms by which carbohydrates are synthesized from carbon dioxide and water using light as an energy source.

Phytoplankton The floating, usually minute, plant life of a body of water.

Planktonic The free-floating or weakly swimming minute animal and plant life of a body of water.

Point Source Any discernible, confined and discrete conveyance from which pollutants are or may be discharged, including, but not limited to, any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation or vessel or other floating craft. This term does not include agricultural stormwater discharges and return flows from irrigated agriculture.

Pollutant Loading Influx of a chemical or nutrient that contaminates air, soil or water.

Pollutant Load Reduction Goal (PLRG) Targeted reduction in pollutant loading to a water body needed to achieve watershed management goals.

Potable Water Water that is safe for human consumption.

Potentiometric Head The level to which water will rise when a well is pierced in a confined aquifer.

Potentiometric Surface An imaginary surface representing the total head of groundwater.

Public Water Supply (PWS) Utilities that provide potable water for public use.

Public Water Supply Demand All potable water supplied by regional water treatment facilities with pumpage of 0.5 million gallons per day or more to all customers, not just residential.

Rationing Mandatory restrictions of a resource sometimes used under drought or other emergency conditions.

Reasonable-Beneficial Use Use of water in such quantity as is necessary for economic and efficient utilization for a purpose, which is both reasonable and consistent with the public interest.

Reclaimed Water Water that has received at least secondary treatment and basic disinfection and is reused after flowing out of a domestic wastewater treatment facility.

RECOVER A comprehensive monitoring and adaptive assessment program formed to perform the following for the Comprehensive Everglades Restoration Program: restoration, coordination and verification.

Recreational Self-Supplied Water Demand The water used for landscape and golf course irrigation. The landscape subcategory includes water used for parks, cemeteries and other irrigation applications greater than 0.1 million gallons per day. The golf course subcategory includes those operations not supplied by a public water supply or regional reuse facility.

Reduced Threshold Areas (RTAs) Areas established by the District for which the threshold separating a General Permit from an Individual Permit has been lowered from the maximum limit of three million gallons per month (100,000 gallons per day) to 600,000 gallons per month (20,000 gallons per day). These areas are typically resource depleted areas with an established history of substandard water quality, saline water movement into ground or surface water bodies, or the lack of water availability to meet projected needs of a region.

Reference Condition. A representation of historic conditions that previously existed in the Loxahatchee River watershed. In this case, the reference condition is based on District staff's interpretation of a set of historical aerial photography and previous vegetation studies that describe the distribution of plant communities along the Northwest Fork at the time that the Loxahatchee was designated as a Wild and Scenic River (1985).

Regional Water Supply Plan (RWSP) Detailed water supply plan developed by the District under Section 373.0361, F.S. ., providing an evaluation of available water supply and projected demands, at the regional scale. The planning process projects future demand for 20 years and develops strategies to meet identified needs.

Reservations of Water (see *Water Reservations*)

Reservoir A man-made or natural water body used for water storage.

Residential Self-Supplied Water Demand (*Same as Domestic Self-Supplied Water Demand*) The water used by households whose primary source of water is private wells and water treatment facilities with pumpages of less than 0.5 million gallons per day.

Restoration Vision. A narrative description of the desired distribution and extent of the physical components and ecological communities that constitute a restored ecosystem (compare to *achievable restoration*).

Restudy Shortened name for C&SF Restudy.

Retrofit The replacement of existing equipment with equipment of higher efficiency.

Retrofitting The replacement of existing water fixtures, appliances and devices with more efficient fixtures, appliances and devices for the purpose of conservation.

Reuse The deliberate application of water that has received at least secondary treatment, in compliance with the Florida Department of Environmental Protection and water management district rules, for a beneficial purpose.

Reverse Osmosis (RO) A membrane process for desalting water using applied pressure to drive the feedwater (source water) through a semipermeable membrane.

Rolling (Moving) Average The arithmetic average of a sequence of data within a data set moved and calculated sequentially to smooth the data and reveal trends (e.g., five-year rolling total phosphorus concentrations).

Saline Water Water with a chloride concentration greater than 250 mg/L, but less than 19,000 mg/L.

Saline Water or Saltwater Interface The hypothetical surface of chloride concentration between fresh water and seawater where the chloride concentration is 250 mg/L at each point on the surface.

Saline Water or Saltwater Intrusion The invasion of a body of fresh water by a body of salt water, due to its greater density. It can occur either in surface water or groundwater bodies. The term is applied to the flooding of freshwater marshes by seawater, the upward migration of seawater into rivers and navigation channels, and the movement of seawater into freshwater aquifers along coastal regions.

Salinity Of or relating to chemical salts (usually measured in parts per thousand, or ppt).

Sapling Juvenile tree that is shorter than canopy height, but taller than breast height.

Save Our Rivers (SOR) In 1981, the Florida Legislature created the Save Our Rivers program for the water management districts to acquire environmentally sensitive land. The legislation produced Section 373.59, F.S., known as the Water Management Lands Trust Fund.

Seawater Water which has a chloride concentration equal to or greater than 19,000 mg/L.

Secchi Disk A black and white disk used to measure the transparency or clarity of water by lowering the disk into the water horizontally and noting the greatest depth at which it can be seen.

Sedimentation The action or process of forming or depositing sediment.

Seedling Juvenile tree shorter than breast height.

Self-Supplied The water used to satisfy a water need, not supplied by a public water supply utility.

Seepage Irrigation Irrigation that conveys water through open ditches. Water is either applied to the soil surface (possibly in furrows) and held for a period of time to allow infiltration, or is applied to the soil subsurface by raising the water table to wet the root zone.

Semi-confining Layers Layers with little or no horizontal flow, restricting the vertical flow of water from one aquifer to another. The rate of vertical flow is dependent on the head differential between the aquifers, as well as the vertical permeability of the sediments in the semi-confining layer.

Sensitivity Analysis An analysis of alternative results based on variations in assumptions (a “what if” analysis).

Serious Harm As defined in Rule 40E-8, F.A.C., the long-term loss of water resource functions resulting from a change in surface or groundwater hydrology.

Significant Harm As defined in Rule 40E-8, F.A.C., the temporary loss of water resource functions, which result from a change in surface or groundwater hydrology, that takes more than two years to recover, but which is considered less severe than serious harm. The specific water resource functions addressed by a MFL and the duration of the recovery period associated with significant harm are defined for each priority water body based on the MFL technical support document.

Silica Silicon dioxide (SiO_2). It occurs in crystalline (quartz), amorphous (opal) or impure (silica sand) forms.

Sinusoidal The real or complex function sin(u) or any function with analogous continuous periodic behavior.

Slough A channel in which water moves sluggishly, or a place of deep muck, mud or mire. Sloughs are wetland habitats that serve as channels for water draining off surrounding uplands and/or wetlands.

South Florida Water Management Model (SFWMM) An integrated surface water-groundwater model that simulates the hydrology and associated water management schemes in the majority of south Florida using climatic data from January 1, 1965, through December 31, 1995. The model simulates the major components of the hydrologic cycle and the current and numerous proposed water management control structures and associated operating rules. It also simulates current and proposed water shortage policies for the different subregions in the system.

Spodic A soil horizon charcterized by illuviation of amorphous substances.

Stage The height of a water surface above an established reference point (datum or elevation).

Standard Project Flood (SPF) A mathematically derived set of hydrologic conditions for a region that defines the water levels that can be expected to occur in a basin during an extreme rainfall event, taking into account all pertinent conditions of location, meteorology, hydrology and topography.

State Facilities Parks, rest areas, visitor welcome centers, buildings, college campuses and other facilities.

Storm Water Surface water resulting from rainfall runoff that does not percolate into the ground or evaporate.

Stormwater Treatment Area (STA) A system of constructed water quality treatment wetlands that use natural biological processes to reduce levels of nutrients and pollutants from surface water runoff.

Stump Sprouts Damaged adult trees that have re-sprouted from a trunk.

Submerged Aquatic Vegetation (SAV) Wetland plants that exist completely below the water surface.

Subregional Groundwater Model A computer model that is used to simulate impacts on a smaller scale than the SFWMM, such as effects within public water supply service areas and impacts of individual wellfields.

Subsidence The loss of soil-bulk caused by the oxidation, decomposition and shrinkage of organic material.

Supply-side Management The conservation of water in Lake Okeechobee to ensure that water demands are met while reducing the risk of serious or significant harm to natural systems.

Surface Water Water that flows, falls or collects above the soil or substrate surface.

Surface Water Improvement and Management (SWIM) Plan A plan prepared pursuant to Chapter 373, F.S.

Surficial Aquifer System (SAS) Often the principal source of water for urban uses within certain areas of south Florida. This aquifer is unconfined, consisting of varying amounts of limestone and sediments that extend from the land surface to the top of an intermediate confining unit.

Swamp A frequently or continuously inundated forested wetland.

Tidal Rivers Water bodies that receive freshwater from areas other than runoff (from the upstream watershed), are flushed to some extent during a tidal cycle, and are subject to saltwater intrusion from downstream areas.

Total Maximum Daily Load (TMDL) The maximum allowed level of pollutant loading for a water body, while still protecting its uses and maintaining compliance with water quality standards, as defined in the *Clean Water Act*.

Trophic Level One of the hierarchical strata of a food web characterized by organisms which are the same number of steps removed from the primary producers

Transmissivity A term used to indicate the rate at which water can be transmitted through a unit width of aquifer under a unit hydraulic gradient. It is a function of the permeability and thickness of the aquifer, and is used to judge its production potential.

Tributary A stream that flows into a larger stream or other body of water.

Truck Farming The horticultural practice of growing one or more vegetable crops on a large scale for shipment to distant markets.

Turbidity The measure of suspended material in a liquid.

Tussock A compact hummock of generally solid ground in a bog or marsh, usually covered with and bound together by the roots of low vegetation, such as grasses or sedges.

Uplands An area with a hydrologic regime that is not sufficiently wet to support vegetation typically adapted to life in saturated soil conditions; nonwetland; upland soils are non-hydric soils.

Valued Ecosystem Component (VEC) A resource-based management strategy similar to a program developed by the EPA as part of the National Estuary Program. For the purposes of this study, the VEC approach is based on the concept that management goals for the Northwest Fork of the Loxahatchee River can best be achieved by providing suitable environmental conditions that will support certain key species, or key groups of species, that inhabit the system.

Vertical Migration The vertical movement of oil, gas, contaminants, water or other liquids through porous and permeable rock.

Wastewater The waterborne discharge from residences, commercial buildings, industrial plants and institutions together with any groundwater, surface runoff or leachate that may be present.

Water Budget An accounting of total water use or projected water use for a given location or activity.

Water Conservation Reducing the demand for water through activities that alter water use practices, e.g., improving efficiency in water use, and reducing losses of water, waste of water and water use.

Water Conservation Areas (WCAs) Part of the original Everglades ecosystem that is now diked and hydrologically controlled for flood control and water supply purposes. These are located in the western portions of Miami-Dade, Broward and Palm Beach counties, and preserve a total of 1,337 square miles, or about 50 percent of the original Everglades.

Water Control District (see *Drainage District*)

Water Preserve Areas (WPA) Multipurpose water-holding areas located along the western border of southeast Florida's urbanized corridor.

Water Reservations State law on water reservations, in Section 373.223(4), F.S., defines water reservations as follows: "The governing board or the department, by regulation, may reserve from use by permit applicants, water in such locations and quantities, and for such seasons of the year, as in its judgment may be required for the protection of fish and wildlife or the public health and safety. Such reservations shall be subject to periodic review and revision in the light of changed conditions. However, all presently existing legal uses of water shall be protected so long as such use is not contrary to the public interest."

Water Resource Caution Areas Areas that have existing water resource problems or are placed where water resource problems are projected to develop during the next 20 years (previously referred to as Critical Water Supply Problem Areas).

Water Resource Development The formulation and implementation of regional water resource management strategies, including the collection and evaluation of surface water and groundwater data; structural and nonstructural programs to protect and manage the water resources; the development of regional water resource implementation programs; the construction, operation and maintenance of major public works facilities to provide for flood control, surface and underground water storage and groundwater recharge augmentation; and related technical assistance to local governments and to government-owned and privately-owned water utilities.

Water Reuse (see *Reuse*)

Watershed A region or area bounded peripherally by a water parting and draining ultimately to a particular watercourse or body of water.

Watershed Management Goals Goals that encompass any one or all of the major water management district responsibilities: flood protection, water supply, water quality and environmental system protection and enhancement. The goals provide the general direction for developing cohesive strategies to manage water resources within a drainage basin, subbasin or segment of a drainage basin or subbasin.

Water Shortage Declaration If there is a possibility that insufficient water will be available within a source class to meet the estimated present and anticipated user demands from that source, or to protect the water resource from serious harm, the governing board may declare a water shortage for the affected source class. (Rule 40E-21.231, F.A.C.) Estimates of the percent reduction in demand required to match available supply is required and identifies which phase of drought restriction is implemented. A gradual progression in severity of restriction is implemented through increasing phases. Once declared, the District is required to notify permitted users by mail of the restrictions and to publish restrictions in area newspapers.

Water Supply Development The planning, design, construction, operation and maintenance of public or private facilities for water collection, production, treatment, transmission or distribution for sale, resale or end use.

Water Year The 12–month period, May 1 through April 30. The water year is designated by the calendar year in which it ends. Therefore, the 2004 water year ends on April 30, 2004

Weir A barrier placed in a stream to control the flow and cause it to fall over a crest. Weirs with known hydraulic characteristics are used to measure flow in open channels.

Wetland An area that is inundated or saturated by surface water or groundwater with vegetation adapted for life under those soil conditions (e.g., swamps, bogs and marshes).

Wetland Drawdown Study Research effort by the South Florida Water Management District to provide a scientific basis for developing wetland protection criteria for water use permitting.

Wild and Scenic River A river as designated under the authority of the of Public Law 90-542, the wild an Scenic Rivers Act as amended, as a means to preserve selected free-flowing rivers in their natural condition and protect the water quality of such rivers. The Loxahatchee River was federally designated as the first Wild and Scenic River in Florida on May 17, 1985.

Xeric Of or pertaining to a habitat having a low or inadequate supply of moisture, or of or pertaining to an organism living in such an environment.

Xeriscape™ Landscaping that involves seven principles: proper planning and design; soil analysis and improvement; practical turf areas; appropriate plant selection; efficient irrigation; mulching; and appropriate maintenance.

Zooplankton The passively floating or weakly swimming, usually minute, animal life of a body of water.

References Cited

Abrahamsan, W.G. and D.C. Hartnett. 1990. Pine flatwoods and dry prairies. In *Ecosystems of Florida*, ed. R.L. Myers and J.J. Ewel. University of Central Florida Press, Orlando, FL, pp. 103-150.

Alexander, T.R. 1967. Bald Cypress and Mangrove Complex of Jonathan Dickinson State Park, Florida. Paper presented at the annual meeting of the Florida Academy of Sciences. March 25-27, 1971.

Alexander, T.R. and A.G. Crook. 1975. *Recent and Long-Term Vegetation Changes and Patterns in South Florida. Part II.* South Florida Ecological Study, National Technical Information Service, PB-264-462.

Allen, D.M. and D.L. Barker. 1990. Interannual variations in larval fish recruitment to estuarine epibenthic habitats. *Marine Ecology Program*, Ser. 63:113-125.

Allen, J.A., J.L. Chambers and D. McKinney. 1994. Intraspecific variation in the response of *Taxodium distichum* seedlings to salinity. *Forest Ecological Management*, 70:203-214.

Allen, J.A., S.R. Pezeshki and J.L. Chambers. 1996. Interaction of flooding and salinity stress on bald cypress (*Taxodium distichum*). *Tree Physiology*, 16:307-313.

Antonini, G.A., P.W. Box, D.A. Fann and M.J. Grella. 1998. *Waterway evaluation and management scheme for the south shore and central embayment of the Loxahatchee River, Florida.* Technical Paper TP-92, Florida Sea Grant College Program, University of Florida, Gainesville, FL.

Applied Technology and Management, Inc. 1994. *Loxahatchee River bathymetric and seagrass survey July, 1994*. Prepared for the Jupiter Inlet District, Jupiter, Florida. 12 pp. plus appendix A-D.

AQUA TERRA Consultants. 1996. *Modifications to HSPF for high water table and wetlands conditions in South Florida.* Final report submitted to South Florida Water Management District, West Palm Beach, FL.

AQUA TERRA Consultants. 1998. *Addition of irrigation module to the HSPH model*. Final report submitted to South Florida Water Management District, West Palm Beach, FL.

ASCE Task Committee on Definition of Criteria for Evaluation of Watershed Models of the Watershed Management Committee, Irrigation and Drainage Division. 1993. Criteria for Evaluation of Watershed Models. *Journal of Irrigation and Drainage Engineering*, 119(3): 429-442.

Avineon, Inc. 2003. *Seagrass coverage of the Loxahatchee Estuary*. Prepared for the South Florida Water Management District through interepretation of aerial photography. Unpublished internal report. South Florida Water Management District. West Palm Beach, FL.

Avineon, Inc. 2004. *Seagrass coverage of the Loxahatchee Estuary (2003)*. Prepared for the South Florida Water Management District through interepretation of aerial photography. Unpublished internal report. South Florida Water Management District. West Palm Beach, FL.

Bahr, L.M. and W.P. Lanier. 1981. *The ecology of intertidal oyster reefs of the south Atlantic Coast: A community profile*. U.S. Department of the Interior, Fish and Wildlife Service, Office of Biological Services Report, FWS/OBS-81/15. 105 pp.

Bancroft, G.T., J.C. Ogden and B.W. Patty. 1988. Wading bird colony formation and turnover relative to rainfall in the Corkscrew Swamp area of Florida during 1982 through 1985. *Wilson Bulletin*, 100(1):50-59.

Benke, A.C. 2001. Importance of flood regime to invertebrate habitat in an unregulated river-floodplain ecosystem. *Journal of the North American Benthological Society,* 20(2):225-240.

Birnhak, B.I. 1974. *An examination of the influence of freshwater canal discharges on salinity in selected southeastern Florida estuaries*. U.S. Department of the Interior, South Florida Environmental Project, Report No. DI-SFEP-74-19. USDOI, Atlanta, GA.

Blaber, S.J.M. 2000. *Tropical estuarine fishes: Ecology, exploitation and conservation*. Blackwell Science, Oxford, UK.

Bortone, S. 2002. *Loxahatchee River valued ecosystem component literature review and recommendation*. Report to the South Florida Water Management District. Submitted by the Conservancy of Southwest Florida. 21 pp.

Breedlove Associates, Inc. 1982. *Environmental investigations of Canal 18 basin and Loxahatchee Slough, Florida*. Final Report to the U.S. Army Corps of Engineers, Gainesville, FL.

Breitburg, D.L. 1989. Demersal schooling prior to settlement by larvae of the naked goby. *Environmental Biology of Fish*, 29(2):97-103.

Breitburg, D.L. 1991. Settlement patterns and presettlement behavior of the naked goby, *Gobiosoma bosci*, a temperate oyster reef fish. *Marine Biology*, 109(2):213-221.

Brewer, S.W. and Rejmanek, M. 1999. Small rodents as significant dispersers of tree seeds in a neotropical forest. *Journal of Vegetative Science*, 10(2):165–174.

Brockmeyer, R.E., Jr. 1989. Patterns of abundance and distribution, and their relation to environmental factors, in the eleotrid fish, *Dormitator maculatus* (Bloch) in the southern Indian River Lagoon system. M.Sc. thesis, Florida Institute of Technology, Melbourne, Florida.

Burke, M.K., S.L. King, D. Gartner and M.H. Eisenbies. 2003. Vegetation, soil, and flooding relationships in a blackwater floodplain forest. *Wetlands,* 23(4):988-1002.

Burnham, K.P., D.R. Anderson, G.C. White, C. Brownie and K.H. Pollock. 1987. Design and analysis methods for fish survival experiments based on release-recapture. *American Fisheries Society* monograph 5. Bethesda, MD. 437 pp.

Burrel, L.V.G., Jr. 1986. *Species profiles: Life histories and environmental requirements of coastal fishes and invertebrates (South Atlantic)-American oyster*. U.S. Fish and Wildlife Services Biology Report 82(11.57). U.S. Army Corps of Engineers.

Carthew, S.M. and Goldingay, R.L. 1997. Non-flying mammals as pollinators. *Trends in Ecological Evolution* 12(3):104–108.

Cary Publications, Inc. 1978. *Loxahatchee Lament* (Volume 1). Jupiter, FL. 360 pp.

CERP Monitoring and Assessment Plan: Part 1 Monitoring and Supporting Research, RECOVER, January, 2004.

Chaplin, J.E. and C. Chaplin. 1968. Fishes of the Bahamas and Adjacent Tropical Waters. Livingston

Chesney, J.E. 1989. Estimating the food requirements of striped bass larvae, *Marone saxatili*s: Effects of light, turbidity, and turbulence. *Marine Ecology Progress Series*, 53:191-200.

Chiu, T.Y. 1975. *Evaluation of salt intrusion in Loxahatchee River, Florida*. Technical Report UFL/COEL–75/013. Coastal and Oceanographic Engineering Laboratory, University of Florida, Gainesville, FL.

Christensen, R.F. 1965. An ichthyological survey of Jupiter Inlet and Loxahatchee River. MS thesis, Florida State University, Tallahassee, FL. 318 pp.

Christensen, R.F. 1973. *A preliminary report on the oyster bars in the Loxahatcheee River in the vicinity of the FECRR trestle*. Technical Report EG488C508. Coastal Engineering Archives, University of Florida, Gainesville, FL.

Coastal Tech. 2004. Modeling Saltwater Barrier in Loxahatchee River Flow.

Conner, W.H. 1994. The effect of salinity and waterlogging on growth and survival of bald cypress and Chinese tallow seedlings. *Journal of Coastal Resources,* 10:1045-1049.

Conner, W.H. and G.R. Askew. 1992. Response of bald cypress and loblolly pine seedlings to short-term saltwater flooding. *Wetlands*, 12(3):230-233.

Cook, S.P., Smith, H.R., Hain, F.P. and Hastings, F.L. 1995. Predation of gypsy moth (*Lepidoptera Lymantriidae*) pupae by invertebrates at low small mammal population densities. *Environmental Entomology,* 24(5):1234–1238.

Craighead, F.C., Sr. 1971. *The trees of south Florida: Volume I: The natural environments and their succession*. University of Miami Press, Coral Gables, Florida.

Cruz, G.A. 1987. Reproductive biology and feeding habits of cuyamel, *Joturus pichardi* and tepemechin, *Agonostomus monticola* (Pisces: Mugilidae) from Rio Platano, Mosquitia, Honduras. *Bulletin of Marine Science,* 40:63-72.

Cubit Engineering Limited. 1986. *Salinity control investigation in the Loxahatchee River.* West Palm Beach, FL.

Cutcher, R.J. 1999. *Environmental restoration program for the Loxahatchee Central Embayment.* Prepared for the Jupiter Inlet District. 44 pp and appendix.

Cutcher, R.J. 2000. *Loxahatchee River bathymetric and seagrass survey.* August 2000. Prepared for the Jupiter Inlet District. 11 pages and appendix.

Cyrus, D.P. and S.J.M. Blaber. 1987a. The influence of turbidity on juvenile fishes in estuaries: Part 1. Field studies at Lake St. Lucia on the southeastern coast of Africa. *Journal of Experimental Marine Biology and Ecology,* 109:53-70.

Cyrus, D.P. and S.J.M. Blaber. 1987b. The influence of turbidity on juvenile marine fishes in estuaries: Part II. Laboratory studies, comparisons with field data and conclusions *Journal of Experimental Marine Biology and Ecology*, 109:71-91.

Dallmeier, F. and J.A. Comiskey. 1998. Forest biodiversity assessment, monitoring, and evaluation for adaptive management. In *Forest biodiversity research, monitoring and modeling: Conceptual background and Old World case studies*, Man and the Biosphere Series, Vol. 20, ed. F. Dallmeier and J.A. Comiskey. UNESCO, Paris, and Parthenon Publishing Group, New York.

Darnell, R.M. 1955. Nocturnal terrestrial habits of the tropical gobioid fish, *Gobiomorus dormitor*, with remarks on its ecology. *Copeia*, 1955(3):237-238.

Darnell, R.M. 1962. Fishes of the Rio Tamesi and related coastal lagoons in east-central Mexico. *Public Institute of Marine Science*, 8: 299-365.

Darst, M., H.M. Light, L.J. Lewis and A.A. Sepulveda. 2003. *Forest types in the lower Suwannee River floodplain, Florida- A report and interactive map*. U.S. Geological Survey Water-Resources Investigations Report 03-4008, 24 pages.

Davenport, J. and O. Vahl. 1979. Responses of the fish *Blennius pholis* to fluctuating salinities. *Marine Ecology Program Series,* 1:101-107.

David, P.G. 1991. *Dupuis Reserve Environmental Assessment*. Technical Memorandum, Environmental Sciences Division Research and Evaluation Department, South Florida Water Management District, West Palm Beach, FL.

Davis, D.A. 1998. Diel movements and microhabitat selection in common snook, *Centropomus undecimalis* and tarpon, *Megalops atlanticus*. M.S. Thesis, Florida Institute of Technology, Melbourne, FL, USA. 186 pp.

Davis, H.C. 1958. Survival and growth of clam and oyster larvae at different salinities. *Biological Bulletin*, 114:296-307.

Davis, J.H., Jr. 1943. Vegetation map of southern Florida. *Florida Geological Survey Bulletin* 25, Figure 71.

Dawes, C.J., C.S. Lobban and D. Tomasko. 1989. A comparison of the physiological ecology of the seagrasses *Halophila decipiens* Ostenfeld and *H. Johnsonii* Eiseman from Florida. *Aquatic Botany,* 33:149-154.

Dawson, C.E. 1970**.** A Mississippi population of the opossum pipefish, *Oostethus lineatus* (Syngnathidae). *Copeia*, 1970:772-773.

Dawson, C.E. 1974. *Pseudophallus brasiliensis* (Pisces: Syngnathidae), a new freshwater pipefish from Brazil. *Proceedings of the Washingon Biological Society*, 87:405-410.

Dawson, C.E. 1979. Review of the Polytypic Doryrhamphine pipefish *Oostethus brachyurus* (Bleeker). *Bulletin of Marine Science,* 29(4):465-480.

Dawson, C.E. 1984. Revision of the genus *Microphis* Kaup (Pisces:Syngnathidae). *Bulletin of Marine Science*, 35(2):117-181.

Dawson, C.E. 1985. *Indo-Pacific pipefishes (Red Sea to the Americas)*. Gulf Coast Research Lab, Ocean Springs, MS. 230 pp.

Dawson, C.E. and R.P. Vari. 1982. *Fishes of the western North Atlantic part eight*. Allen Press, Inc., Lawrence, KS. 198 pp.

Day, J.W., Jr., C.A.S. Hall, W.M. Kemp, and A. Ynez-Arancibia. 1989. *Estuarine ecology*. John Wiley and Sons, New York. 558 pp.

Dege, M. and L.R. Brown. 2004. Effect of outflow on spring and summertime distribution and abundance of larval and juvenile fishes in the upper San Francisco estuary, In *Early life history of fishes in the San Francisco Estuary and Watershed*, ed. F. Feyrer, L.R. Brown, R.L. Brown and J.J. Orsi. American Fish Society Symposium. 39.

Dent, R.C. 1997. *Rainfall observations in the Loxahatchee River Watershed*. Loxahatchee River District, Jupiter, Florida

Dent, R.C. 2001. *Trophic state of the Loxahatchee River Estuary*. Loxahatchee River District, Jupiter, FL.

Dent, R.C., L.R. Bachman and M.S. Ridler. 1998. *Profile of the benthic macroinvertebrates in the Loxahatchee River Estuary*. Wildpine Ecological Laboratory, Loxahatchee River District, Jupiter, FL.

De Vries, M.C., R.B. Forward and W.F. Hettler. 1995. Behavioral response of larval Atlantic menhaden, *Brevoortia tyrannus* (Latrobe) and spot *Leiostomus xanthurus* (Lacepede) to rates of salinity change. *Journal of Experimental Marine Biolology and Ecology,* 185:93-108.

Dodson, J.J., C. Dauvin, R. Ingram and D.B. D'Anglejan. 1989. Abundance of larval rainbow smelt (*Osmerus mordax*) in relation to the maximum turbidity zone and associated macroplanktonic fauna of the middle St. Lawrence Estuary. *Estuaries,* 66-81.

Doering, P.H. and R.H. Chamberlain. 2000. Experimental studies on the salinity tolerance of turtle grass, *Thalassia testudinum*. In *Seagrass: Monitoring, ecology, physiology, and management,* ed. S.A. Bortone. CRC Press, Boca Raton, FL, pp. 81-97.

Doering P.H., R.H. Chamberlain and D.E. Haunert. 2002. Using submerged aquatic vegetation to establish minimum and maximum freshwater inflows to the Caloosahatchee estuary, Florida. *Estuaries,* 25(6B):1343-1354.

Donigian, A.S., J.C. Imoff, B.R. Bicknell and J.L. Kittle. 1984. *Application guide for Hydrological Simulation Program – FORTRAN (HSPF)*. EPA-600/3-84-065. USEPA, Athens, GA.

Drew, R.D. and N.S. Schomer. 1984. *An ecological characterization of the Caloosahatchee River/Big Cypress Watershed*. U.S. Fish and Wildlife Service, Office of Biological Services, Washington, D.C. FWS/0BS–82/58.2. 225 pp.

Dubois, Bessie Wilson. 1981. History of the Loxahatchee River, Jupiter, Florida. 29 pp.

Duever, M.J., J.F. Meeder and L.C. Duever. 1984. Ecosystems of the Big Cypress Swamp. In *Cypress swamps*, ed. K.C. Ewel and H.T. Odum. University of Florida Press, Gainesville, FL, pp. 294–302.

EarthTech, Inc. 1999 (or 2000?). *Final hydraulic report, Kitching Creek water quality improvement project.* Report to Martin County, Stuart, FL. July 10, 2000.

E&E Consultant Team. 2004. *Procedural approach for ecological benefit and impact analyses of alternative plans: North Palm Beach County-Part 1 Watershed Wetlands.*

Engeman, R.M., B. Constantin, M. Nelson, J. Woolard and J. Bourassa. 2001. Monitoring changes in feral swine abundance and spatial distribution. *Environmental Conservation*, 28(3):235-240.

Ewel, K.C. 1990. Multiple demands on wetlands. *Bioscience,* 40:660-666.

Fleming, T.H. and V.J. Sosa. 1994. Effects of nectarivorous and frugivorous mammals on reproductive success of plants. *Journal of Mammalogy,* 75(4):845–851.

Florida Department of Environmental Protection. 1998. *Loxahatchee River Watershed action plan*. Second Draft. FDEP, Tallahassee, FL.

Florida Department of Environmental Protection. 2000. *Jonathan Dickinson Park unit management plan*. FDEP, West Palm Beach, FL. Final Draft.

Florida Department of Environmental Protection. 2002. *Loxahatchee River Watershed action plan*. FDEP, West Palm Beach, FL. Final Draft.

Florida Department of Environmental Protection. 2003a. *Guide to the natural communities of Florida and 2050 plant communities,* Fire and Hydrology Draft.

Florida Department of Environmental Protection. 2003b. *Basin status report: St. Lucie and Loxahatchee*. FDEP.

Florida Department of Environmental Protection and South Florida Water Management District. 2000. *Loxahatchee River Wild and Scenic River management plan*. FDEP and SFWMD. West Palm Beach, FL. Plan Update.

Florida Department of Environmental Protection and South Florida Water Management District. (in preparation). *Ecological studies in the floodplain forest of the Loxahatchee River and its major tributaries, southeast Florida*. FDEP AND SFWMD. West Palm Beach, FL.

Florida Department of Natural Resources. 1985. *Loxahatchee River National Wild and Scenic River management plan*. FDNR Tallahassee, FL. 221 pp.

Fonseca, M.S. 1989. Sediment stabilization by *Halophila decipiens* in comparison to other seagrasses. *Estuarine Coastal Shelf Science,* 29:501-507.

Fonseca, M.S. and J.A. Cahalan. 1992. A preliminary evaluation of wave attentuation by four species of seagrass. *Estuarine Coastal Shelf Science,* 35:565-576.

Fonseca, M.S. and J.S. Fisher. 1986. A comparison of canopy friction and sediment movement between four species of seagrass with reference to their ecology and distribution. *Marine Ecology Program Series*, 29:15-22.

Fonseca, M.S., J.C. Zieman, G.W. Thayer and J.S. Fisher. 1983. The role of current velocity in structuring eelgrass (*Zostera marina*) meadows. *Estuarine Coastal Shelf Science*, 17:367-380.

Frey, D.G. 1946. *Oyster bars of the Potomac River*. U.S. Fish and Wildlife Service Special Report. 32:1-93.

Gilbert, C.R. and D.P. Kelso. 1971. Fishes of the Tortuguero area, Caribbean Costa Rica. *Bulletin Florida State Museum, Biological Science*, 16(1):1-54.

Gilmore, R.G. 1977a. Notes on the opossum pipefish, *Oostethus lineatus* from the Indian River lagoon and vicinity, Florida. *Copeia,* 1977:781-783.

Gilmore, R.G. 1977b. Fishes of the Indian River Lagoon and adjacent waters, Florida. *Bulletin Florida State Museum, Biological Science*, 22(3):101-148.

Gilmore, R.G. 1984. *Fish and macrocrustacean population dynamics in a tidally influnced impounded subtropical salt marsh*. Final Report. Florida Department of Environmental Regulation – Coastal Zone Management Contract No. 47/73. 35 pp., 20 tables, 31 figures.

Gilmore, R.G. 1987a. Fish, macrocrustacean and avian population dynamics and cohabitation in tidally influenced impounded subtropical wetlands. In *Proceedings of a symposium on waterfowl and wetlands management in the coastal zone of the Atlantic flyway*, ed. W.R. Whitman and W.H. Meredith, Delaware Department of Natural Resources and Environmental Control, Dover, Delaware.

Gilmore, R.G. 1987b. Subtropical-tropical seagrass communities of the Southeastern United States: Fishes and fish communities, In *Proceedings of the symposium on subtropical-tropical seagrasses of the Southeastern United States*, ed. M.J. Durako, R.C. Phillips and R.R. Lewis. Marine Research Publication 42, Florida Department of Natural Resources.

Gilmore, R.G. 1988. Subtropical seagrass fish communities, population dynamics, species guilds and microhabitat associations in the Indian River Lagoon. Ph.D. Dissertation, Florida Institute of Technology, Melbourne, Florida. i-xvii, 199 pp.

Gilmore, R.G. 1995. Environmental and biogeographic factors influencing ichthyofaunal diversity: Indian River Lagoon. *Bulletin of Marine Science*, 57:153-170.

Gilmore, R.G. 2001. The evolution of the Florida fish fauna. *Proceedings of the Bulletin of the Gulf and Caribbean Fisheries Institute*.

Gilmore, R.G. Jr. 2002. Chapter 11: Sound production in the spotted seatrout. In *The biology of the spotted seatrout*, ed. S.A. Bortone. CRC Press, Boca Raton, FL.

Gilmore, R.G. and R. Eames. 1987. *Fish, macrocrustacean and hydrological studies of an impounded subtropical high marsh.* Final Report: Florida Department of Environmental Regulations, Coastal Zone Management Contract No. 167. 17 pp.

Gilmore, R.G. and C.R. Gilbert. 1992. Coastal habitat description and species accounts for *Microphis brachyurus lineatus, Gobiomorus dormitor, Awaous tajasica, Gobionellus pseudofasciatus, Bairdiella sanctaeluciae* and *G. stigmaturus.* In *Rare and endangered biota of Florida: Volume four, Fishes,* ed. C.R. Gilbert. University of Florida Press, 247 pp.

Gilmore, R.G. and P.A. Hastings. 1983. Observations on the ecology and distribution of certain tropical peripheral fishes in Florida. *Florida Scientist,* 46:31-51.

Gilmore, R.G. and J.J. Peters. 1986. *Rotational management impoundment affects on fish, macrocrustacean and avian population dynamics and basic hydrological parameters.* Final Report, Florida Department of Environmental Regulation, Coastal Zone Management Contract No. 122. 78 pp.

Gilmore, R.G. and M.S. Peterson. 1989. *Interspecific differences in metabolic adaptations to hypoxia and mass mortalities of impounded salt marsh and mangrove swamp fishes.* Final Report: Florida Department of Environmental Regulation, Coastal Zone Management – 194 (II) through the Indian River Mosquito Control District.

Gilmore, R.G. and S.C. Snedaker. 1993. Chapter 5: Mangrove forests. In *Biodiversity of the southeastern United States: Lowland terrestrial communities,* ed. W.H. Martin, S.G. Boyce and A.C. Echtemacht. John Wiley & Sons, Inc., New York. 502 pp.

Gilmore, R.G., Cooke, D.W. and C.J. Donohoe. 1982. A comparison of the fish populations and habitat in open and closed salt marsh impoundments in east-central Florida. *North East Gulf Sciences,* 5:25-37.

Gilmore, R.G., C.J. Donohoe and D.W. Cooke. 1983. Observations on the distribution and biology of east-central Florida populations of the common snook, *Centropomus undecimalis* (Bloch). *Florida Scientist,* Special Supplemental Issue, 46: 313-336.

Gilmore, R.G., R.E. Brockmeyer, D.M Scheidt and S.J. VanderKooy. 1992. *Final Report: Nekton sampling program evaluation of faunal utilization of a created tidal marsh, Grand Harbor, Indian River County, Florida*. 20 pp.

Gilmore, R.G., P.B. Hood and J.J Luczkovich. 1987. *Fishes occurring within a breached saltmarsh impoundment (Number 19B) in St. Lucie County, Florida: A report for the St. Lucie County Mosquito Control District.* Harbor Branch Oceanographic Institute, Work Order No. 705314. 7 pp., 2 tbls, 1 fig.

Gilmore, R.G., B.J. McLaughlin and D.M. Tremain. 1986. *Fish and macrocrustacean utilization of an impounded and managed red mangrove swamp with a discussion of the resource value of managed mangrove swamp habitat*. Final Report: Homer Hoyt Institute. 132 pp.

Gilmore, R.G., P.B. Hood, R.E. Brockmeyer, Jr. and D.M. Scheidt. 1985. *Final report salt marsh fishery management and restoration technique analysis*. Florida Sea Grant Project No. R/C-E-23 (E/T-3-PD). 50 pp., 15 tbls, 56 figs.

Gilmore, R.G., P.B. Hood, R.E. Brockmeyer, Jr. and D.M. Scheidt. 1986. *Final Report: Impoundment No. 16A and 24, St. Lucie County, John Smith Impoundment, Brevard County, Florida: Water control systems and their hydrological impact*. Florida Department of Health and Rehabilitative Services, Contract No. LD704. 63 pp. 20 tbls, 79 figs.

Gilmore, R.G., P.B. Hood, R.E. Brockmeyer, Jr., and D.M. Scheidt. 1987. *Final Report: Effects of increased culvert density on utilization of marsh impoundments by fishes and macrocrustaceans.* Florida Department of Health and Rehabilitative Services Contract No. LD703. 43 pp., 21 tbls, 46 figs.

Gilmore, R.G., D.J. Peters, J.L. Fyfe and P.D. O'Brian. 1985. *Fish, macrocrustacean and avian dynamics in a tidally influenced impounded subtropical salt marsh*. Final Report, Florida Department of Environmental Regulation, Coastal Zone Management, Contract No 193. 42 pp. and appendix.

Gilmore, R.G., D. Scheidt, R. Brockmeyer and S. VanderKooy. 1990. *Final Report: Spatial and temporal dynamics of secondary productivity in high marsh habitats vegetated with algae, herbaceous and woody flora under natural and managed hydrological cycles.* Florida Department of Environmental Regulation, Coastal Zone Management CZM-258, through the Indian River Mosquito Control District. 21 pp., 8 tbls, 21 figs.

Gonzalez, J.A. 2004. *Rating improvements for Lainhart Dam, SCADA & hydro data management.* SFWMD Technical Publication SHDM #1. (June 2004)

Gonzalez, J.A. 2005. *Assessment of tidal effect on the stage-discharge relations for four Loxahatchee River stations during low-flows by direct measurements*. SFWMD Technical Publication SHDM# ---

Greene, H.W. 1988. Species richness in tropical predators, In *Diversity and conservation of tropical rainforests*, ed. F. Almeda and C.M. Pringle. California Academy of Science, San Francisco.

Gregory, S.V., F.J. Swanson, W.A. McKee and K.W. Cummins. 1991. An ecosystem perspective of riparian zones. *Bioscience,* 41:540-551.

Gunderson, L.H. 1984. Regeneration of cypress in logged and burned strands at Corkscrew Swamp Sanctuary, Florida. In *Cypress swamps*, ed. K.C. Ewel and H.T. Odum. University Presses of Florida, Gainesville, FL, pp. 349-357.

Gunter, G. 1961. Some relations of estuarine organizms to salinity. *Limnology and Oceanography,* 6:182-190.

Hamrick, J.M. 1992. *A three-dimensional environmental fluid dynamics computer code: Theoretical and computational aspects.* The College of William and Mary, Virginia Institute of Marine Science. Special Paper 317, 63 pp.

Harris, L.D. and C.R. Vickers. 1984. Some faunal community characteristics of cypress ponds and the changes induced by perturbations. In *Cypress swamp*s, ed. K.C. Ewel and H.T. Odum. University of Florida Press, Gainesville.

Harvey, B.C. 1987. Susceptibility of young-of-year fishes to downstream displacement by flooding. *Transactions of the American Fisheries Society*, 116:851-855.

Harwell, M.A., J.F. Long, A.M. Bartuska, J.H. Gentile, C.C. Harwell, V. Myers and J.C. Ogden. 1996. Ecosystem management to achieve ecological sustainablility: The case of South Florida. *Environmental Management*, 20:497-521.

Hastings, P.A. and S.A. Bortone. 1976. Additional notes on tropical marine fishes in the northern Gulf of Mexico. *Florida Scientist,* 39:123-125.

Heald, E.J. and W.E. Odum. 1970. The contribution of mangrove swamps to Florida fisheries. *Proceedings of the Gulf and Caribbean Fisheries Institute,* 22:130-135.

Hedgepeth, M.Y. (unpublished). *Ecological comparisons of ichthyofaunal communities in Lake Worth and Loxahatchee River, Palm Beach and Martin Counties, Southeastern Florida with special references to the effects of anthropogenic changes*. Florida Marine Research Institute, St. Petersburg, FL.

Hedgepeth, M., T. Fucigna and S. Myers. 2001. *The relationship between ichthyofaunal communities and salinity on the Loxahatchee River*. Paper presented at the Loxahatchee River Science Symposium, Jupiter, FL.

Henshall, J.A. 1888. Camping and cruising in Florida: An account of two winters passed in cruising around the coasts of Florida as viewed from the standpoint of an angler, a sportsman, a yachtman, a naturalist and a physician. Robert Clarke & Co., Cincinnati, OH.

Hill, G.W. 1977. *Loxahatchee River oyster bar removal project: Salinity monitoring phase*. Final Letter Report. U.S. Geological Survey Water Resources Division, Jupiter, FL.

Holmes, R.M., B.J. Peterson, L.A. Deegan, J.E. Hughes and B. Fry 2000. Nitrogen biogeochemistry in the oligohaline zone of a New England estuary. *Ecology*, 81(2):416-432.

Houde, E.D. 1994. Differences between marine and freshwater fish larvae: Implications for recruitment. *ICES Journal of Marine Science,* 51:91-97.

Hu, G. 2002. The effects of freshwater inflow, inlet conveyance and sea level rise on the salinity regime in the Loxahatchee Estuary. *Proceedings of 2002 Environmental Engineering Conference, Environmental & Water Resources Institute, American Society of Civil Engineers-Canadian Society of Civil Engineers*, Niagara Falls, Ontario, Canada, July 21-24, 2002.

Hu, G. 2004. Modeling study of saltwater intrusion in Loxahatchee River, Florida. West Palm Beach, FL. *Proceedings of the Eighth Annual Conference of Estuarine and Coastal Modeling*. *American Society of Civil Engineers*, pp. 667-680.

Janos, D.P., C.T. Sahley and L.H. Emmons. 1995. Rodent dispersal of vesicular-arbuscular mycorrhizal fungi in Amazonian Peru. *Ecology,* 76(6):1852–1858.

Janson, C.H., J.W. Terborgh and L.H. Emmons. 1981, Non-flying mammals as pollinating agents in the Amazonian forest. *Biotropica,* 13(suppl.):1–6.

Jassby, A.D., W.J. Kimmerer, S.G. Monismith, C. Armor, J.E. Cloern, T.M. Powell, J.R. Schubel and T.J. Vendlinski. 1995. Isohaline position as a habitat indicator for estuarine populations. *Ecological Applications,* 5:272-289.

Jupiter Inlet District Management. 1993. *Plan for the Loxahatchee River*.

Kenworthy, W.J., G.W. Thayer and M.S. Fonseca. 1988. The utilization of seagrass meadows by fishery organisms. In *The ecology and management of wetlands, Vol. 1. Ecology of wetlands*, ed. D.D. Hook, et al. Timber Press, Portland, OR, pp. 548-560.

Kimmerer, W.J. 2002a. Effects of freshwater flow on abundance of estuarine organisms: Physical effects or trophic linkages. *Marine Ecology Program Series*, 243:39-55.

Kimmerer, W.J. 2002b. Physical, biological and management responses to variable freshwater flow into the San Francisco Estuary. *Estuaries,* 25:1275-1290.

Kimmerer, W.J., J.R. Burau and W.A. Bennett. 2002. Persistance of tidally-oriented vertical migration by zooplankton in a temperate estuary. *Estuaries*, 25:359-371.

Kinzie, R.A. 1988. Habitat utilization by Hawaiian stream fishes with reference to community structure in oceanic island streams. *Environmental Biology of Fishes*, 22:179-192.

Klemm, J. and C. Vare. 1985. *A 1985 seagrass map depicting the Loxahatchee River basin area*. Palm Beach County Health Department. 5 page report and map.

Krauss, K.W., J.L. Chambers and J.A. Allen. 1998. Salinity effects and differential germination of several half-sib families of bald cypress from different seed sources. *New Forests*, 15:53-68.

Krauss, K.W., J.L. Chambers, J.A. Allen, D.M., Soileau and A.S. De Boisier. 2000. Growth and nutrition of bald cypress families planted under varying salinity regimes in Louisiana, USA. *Journal of Coastal Research*, 16(1):153-163.

Law Environmental, Inc. 1991a. *West Loxahatchee River management plan*. Submitted to the Jupiter Inlet District, Jupiter, FL.

Law Environmental, Inc. 1991b. *Technical assessment report for the West Loxahatchee River, Volume I. Environmental, recreation, and engineering*. Project No. 55-9743.

Lewis, F.G., III. 1984. Distribution of macrobenthic crustaceans associated with *Thalassia*, *Halodule*, and bare sand substrata. *Marine Ecology Progress Series*, 19:101-113.

Lewis, R.R. III, R.G. Gilmore, Jr., D.W. Crewz and W.E. Odum. 1985. Mangrove habitat and fishery resources of Florida. pp. 281-336. In *Florida aquatic habitat and fishery resources*, ed. W. Seaman, Jr. Florida Chapter, American Fisheries Society, Kissimmee, FL. 543 pp.

Li, Y. and R. Munoz-Carpena. 2004, unpublished. *Soils and hydroperiod analysis in the floodplains of the Loxahatchee River Watershed*, University of Florida, IFAS.

Light, H.M., M.R. Darst, L.J. Lewis and D.A. Howell. 2003. *Hydrology, vegetation and soils of riverine and tidal floodplains of the lower Suwannee River, Florida, and potential impacts of flow reductions*. USGS Professional Paper 1656A, 98 pp.

Lirman, D. and W.P. Cropper, Jr. 2003. The influence of salinity on seagrass growth, survivorship, and distribution within Biscayne Bay, Florida: Field, experimental, and modeling studies. *Estuaries,* 26(1):131-141.

Liu, G., Y. Li and R. Munoz-Carpena. 2005. *The effects of salinity and altered hydrology on the growth, survival and restoration of bald cypress, (Taxodium distichum) (L) Rich. seedlings from the tidal floodplains of the Loxahatchee River Watershed.* University of Florida, IFAS, Tropical Research and Education Center Report TREC-LI05-12 for South Florida Water Management District, 55 pp.

Loosanoff, V.L. 1946. Feeding of oysters in relation to tidal stages and to periods of light and darkness. *Biological Bulletin Woods Hole,* 90(3):244-264.

Loosanoff, V.L. 1953. Behavior of oysters in water of low salinity. *Proceedings of the National Shellfisheries Association,* 43:135-151.

Loosanoff, V.L. 1965. The American or eastern oyster. *United States Department of the Interior Circular*, 205:1-36.

Lowe-McConnell, R.H. 1987. *Ecological studies in tropical fish communities*. Cambridge University Press, Cambridge, UK. 382 pp.

Lowerre-Barbieri, S.K., F.R Vose and J.A. Whittington. 2003. Catch-and-release fishing on a spawning aggregration of common snook: Does it affect reproductive output? *Transactions American Fishery Society,* 132:940-952.

Loxahatchee River District. 2004. *Seagrass species distribution in the Loxahatchee River Estuary*. Prepared by the Wildpine Ecological Laboratory for the South Florida Water Management District. 5 pp. plus an appendix.

Luczkovich, J.J., S.F. Norton and R.G. Gilmore. 1995. The influence of oral anatomy on prey selection during the ontogeny of two percoid fishes, *Lagodon rhomboide*s and *Centropomus unidecimalis*. *Environomental Biology Fishes*, 44:79-95.

Lyons, J. and D.W. Schneider. 1990. Factors influencing fish distribution and community structure in a small coastal river in southwestern Costa Rica. *Hydrobiologia*, 203:1-14.

Karr, J.R. 1981. Assessment of biotic integrity using fish communities. Fisherues 6: 21-27.

Karr, J.R. 1991. Biological integrity: a long-neglected aspect of water resource management. Ecological Apllications 1: 66-84.

Mallen-Cooper, M. 1999. Developing fishways for nonsalmonid fishes: A case study from the Marray River in Australia. In *Innovations in fish passage technology,* ed. M. Odeh. Pp. 173-196.

Martin, T.J. 1988. Interaction of salinity and temperature as a mechanism for spatial separation of three co-existing species of Ambassidae (Cuvier) (Teleostei) in estuaries on the south-east coast of Africa. *Journal Fisheries Biology*, 33:9-15.

Martin County Growth Management Department. 2000. *Loxahatchee River Basin wetland planning project for Martin County*. Final Report to United States Environmental Protection Agency (EPA), Atlanta, GA.

MacCready, P. 2004. Toward a unified theory of tidally-averaged estuarine salinity structure. *Estuaries*, 27(4):561-570.

McDowall, R.M. 1988. *Diadromy in fishes*. Timber Press, Portland, OR. 308 pp.

McKaye, K.R., D.J. Weiland and T.M. Lim. 1979. Comments on the breeding biology of *Gobiomorus dormitor* (Osteichthyes: Eleotridae) and the advantage of school behavior to its fry. *Copeia*, 542-544.

McLane, W.M. 1955. *The fishes of the St. Johns River system*, Ph.D. dissertation, University of Florida, Gainesville, FL.

McMahan, C. 1968. Biomass and salinity tolerance of shoalgrass and manateegrass in Lower Laguna Madre, Texas. *Journal of Wildlife Management,* 32(3):501-506.

McMichael, R.H., Jr., K.M. Peters and G.R. Pasrons. 1989. Early life history of the snook, *Centropomus undecimalis*, in Tampa Bay, Florida. *Northeast Gulf Science*, 10(2):113-125.

McMillan, C. 1974. Salt tolerance of mangroves and submerged aquatic plants. In *Ecology of halophytes,* ed. R.J. Reimold and W.H. Queen. Academic Press, New York, pp. 379-399.

McPherson, B.F. 1981. *The cypress forest community in the tidal Loxahatchee River Estuary: Distribution, tree stress, and salinity*. USGS Internal Report.

McPherson, B.F. and R. Halley. 1996. *The South Florida Environment: A Region under Stress*. U.S. Geological Survey Circular 1134.

McPherson, B.F., M. Sabanskas and W.A. Long. 1982. *Physical, hydrological, and biological characteristics of the Loxhathcee River Estuary, Florida.* U.S. Geological Survey Water-Resources Investigations Open-File Report 82-350. Tallahassee, Florida.

McPherson, B.F., W.H. Sonntag and M. Sabanskas. 1984. Fouling community of the Loxahatchee River estuary, Florida, 1980-81. *Estuaries,* 7(2):149-157.

Merritt, R.W. and K.W. Cummins. 1996. *An introduction to the aquatic insects of North America.* Kendall/Hunt Publishing Company.

Meshaka, W.E., 2001. *The Cuban Treefrog in Florida: Life history of a successful colonizing species*. University Press of Florida. Gainesville, FL.

Miller, J.M., L.B. Crowder and M.L. Moser. 1985. Migration and utilization of estuarine nurseries by juvenile fishes: An evolutionary perspective. *Marine Science,* 27:338-352.

Miller, R.E. and B.E. Gunsalus. 1997. *Wetland rapid assessment procedure*. Technical Publication RED-001, Natural Resources Management Division Regulation Department, South Florida Water Management District.

Mitsch, W.J. and J.G. Gosselink. 1993. *Wetlands,* 2nd ed. Van Nostrand Reinhold Publication, New York.

Moser, M.I. and S.W. Ross. YEAR. Effects of changing current regime and river discharge on the estuarine phase of anadromous fish migration, pp. 343-347. In *Changes in fluxes in estuaries*, ECSA22/ERF Symposium, K.R. Dyer and R.J. Orth, eds. Oleson and Oleson, Fredenborg, Denmark.

Myers, G.S. 1966. Derivation of the freshwater fish fauna of Central America. *Copeia,* 766-773.

Myers, R.L. 1990. Scrub and high pine. In *Ecosystems of Florida,* ed. R.L. Myers and J.J. Ewel. University of Central Florida Press, Orlando, pp. 150-194.

Nellis, D.W. 2001. *Common coastal birds of Florida and the Caribbean*. Pineapple Press, Inc., Sarasota, FL.

Nordlie, F.G. 1979. Niche specificities of eleotrid fishes in a tropical estuary. *Revista Biologie Tropical*, 27(1):35-50.

Nordlie, F.G. 1981. Feeding and reproductive biology of eleotrid fishes in a tropical estuary. *Journal of Fish Biology*, 18:97-110.

North, E.W. and E.D. Houde. 2001. Retention of white perch and striped bass larvae: Biological-physical interactions in Chesapeake Bay estuarine turbidity maximum. *Estuaries*, 24:756-769.

Odum, E.W. and C.C. McIvor. 1991. Mangroves. In *Ecosystems of Florida*, ed. R.L. Myers and J.J. Ewel. University of Central Florida Press, Orlando, pp. 517-548.

Odum, E.W., C.C. McIvor and T.J. Smith, III. 1982. *The ecology of the mangroves of south Florida: A community profile*. U.S. Fish and Wildlife Reference OBS-81-24.

Olson, N.W., S.K. Wilson and D.W. Willis. 2004. Effect of spatial variation on zooplankton community assessment in fishery studies. *Fisheries*, 29(4):17-22.

Packard, J.M. 1981. *Abundance, distribution, and feeding habits of manatees (Trichechus manatus) wintering between St. Lucie and Palm Beach Inlets, Florida*. Final Report. U.S. Fish and Wildlife Service: 142 pp.

Palmer, T.A., P.A. Montagna and R.D. Kalke. 2002. Downstream effects of restored freshwater inflow to Rincon Bayou, Nueces Delta, Texas, USA. *Estuaries*, 25:1446-1456.

Paperno, R. and R.B. Brodie. 2004. Effects of environmental variables upon the spatial and temporal structure of a fish community in a small, freshwater tributary of the Indian River Lagoon, Florida. *Estuarine Coastal Shelf Science*, 61:229-241.

Parenti, L.R. and G.R. Allen. 1991. Fishes of the Gogol River and other coastal habitats, Madang Province, Papua, New Guinea. *Ichthyological Exploration of Freshwaters*, 1(4):307-320.

Pearse, A.S. and G. Gunter. 1957. Salinity. In *Treatise on marine ecology and paloecology*, ed. J.W. Hedgpeth. Geological Society America Memoir, 67:1296 pp.

Pearse, A.S. and G.W. Wharton. 1938. The oyster "leech," *Stylochus inimicus* Palombi, associated with oysters on the coasts of Florida. *Ecological Monographs*, 8:605-655.

Peters, K.M., R.E. Matheson, Jr. and R.G. Taylor. 1998. Reproduction and early life history of common snook, *Centropomus undecimalis* (Block), in Florida. *Bulletin of Marine Science*, 62(2):509-529.

Peterson, M.S. and R.G. Gilmore, Jr. 1991. Eco-physiology of juvenile snook *Centropomus undecimalis* (Blooch): Life-history implications. *Bulletin of Marine Science* 48:46-57.

Peterson, M.S. and M.R. Meador. 1994. Effects of salinity on freshwater fishes in coastal plain drainages in the Southeastern U.S. *Review of Fisheries Science*, 2(2):95-121.

Peterson, M.S. and S.J. VanderKooy. 1995. Phenology and spatial and temporal distribution of larval fishes in a partial channelized warmwater stream. *Ecology of Freshwater Fish*, 4:93-105.

Pezeshke, S.R. 1990. A comparative study of the response of *Taxodium distichum* and *Nyssa aquatic* seedlings to soil anaerobiosis and salinity. *Forest Ecological Management,* 33(34):531-541.

Pezeshki, S.R., R.D. Delaune and H.S. Choi, Jr. 1995. Gas exchange and growth of bal dypress seedlings from selected U.S. Gulf Coast populations: Responses to elevated salinities. *Canadian Journal of Forest Research*, 25:1409-1415.

Phillips, R.C. 1984. *The ecology of eelgrass meadows in the Pacific northwest: A community profile*. U.S. Fish and Wildlife Service USFWS/OBS-84/24. 85 pp.

Poff, N.L., J.D. Allan, M.B. Bain, J.R. Karr, K.L. Prestegaard, B.D. Richter, R.E. Sparks and J.C. Stromberg. 1997. The natural flow regime: A paradigm of river conservation and restoration. *Bioscience* 47:769-784.

Powell, A.B., D.E. Hoss, W.F. Hettler, D.S. Peters and S. Wagner. 1989. Abundance and distribution of ichthyoplankton in Florida Bay and adjacent waters. *Bulletin of Marine Science* 44(1):35-48.

Power, M.E. 1987. Predator avoidance by grazing fishes in temperate and tropical streams: Importance of stream depth and prey size. In *Predation: Direct and indirect impacts on aquatic communities,* ed. W.C. Kerfoot and A. Sih. University Press New England, Hanover, NH, pp. 333-351.

Power, M.E. 1984a. Depth distribution of armored catfish: Predator-induced avoidance? *Ecology*, 65:523-528.

Power, M.E. 1984b. Habitat quality and the distribution of algae-grazing catfish in a Panamanian stream. *Journal of Animal Ecology* 53:357-374.

Radtke, R.L, R.A. Kinzie and S.D. Folson. 1988. Age at recruitment of Hawaiian freshwater gobies. *Environmental Biology of Fishes*, 23:205-213.

Rakocinski, C.F., D.M. Baltz and J.W. Fleeger. 1992. Correspondence between environmental gradients and the community structure of marsh-edge fishes in a Louisiana estuary. *Marine Ecology Program Series,* 80:135-148.

Ray, S.M. and R.L. Benefield. 1997. Present and future challenges facing the Texas oyster fishery. *Journal of Shellfish Research,* 16:31.

Reddering, J.S. 1988. Prediction of the effects of reduced river discharge on estuaries of the south-eastern Cape Province, South Africa. *South African Journal of Science*, 84:726-730.

Richards, W.J. 1984. *Kinds and abundances of fish larvae in the Caribbean Sea and adjacent areas*. NOAA, Technical Report NMFS-SSRF-776. 54 pp.

Ridler, M.S., R.C. Dent and L.R. Bachman. 1999. *Distribution, density and composition of seagrasses in the southernmost reach of the Indian River Lagoon*. Loxahatchee River District.

Ridler, M.S., R.C. Dent and L.R. Bachman. 2000. *An evaluation of seagrass communities in the southernmost reach of the Indian River Lagoon*. Loxahatchee River District. 16 pp. plus figures.

Ridler, M.S., R.C. Dent and L.R. Bachman. 2003. *Viability and variability of seagrass communities in the Loxahatchee Estuary and associated reach of the Indian River Lagoon*. Loxahatchee River District. 17 pp. plus appendix.

Ringold, P.L., B. Mulder, J. Alegria, R.L. Czaplewski, T. Tolle and K. Burnett. 2003. Design of an ecological monitoring strategy for the forest plan in the Pacific Northwest. In *Monitoring ecosystems: Interdisciplinary approaches for evaluating ecoregional initiatives*, ed. D.E. Busch and J.C. Trexler. Island Press, Washington, DC. pp. 73-99.

Roberts, Richard. Personal communication, December 8, 2004.

Roberts, R., R. Woodbury and J. Popenoe. (in press). *Vascular Plants of Jonathan Dickinson State Park*. Biological Sciences. *Florida Scientist*.

Robinson, A.T., R.W. Clarkson, and R.E. Forrest. 1998. Dispersal of larval fishes in a regulated river tributary. *Transactions of the American Fisheries Society*, 127:772-786.

Rodis, H.G. 1973. *Encroaching salt water in northeast Palm Beach County, Florida. U.S.* Geological Survey with Palm Beach County Board of Commissioners, Tallahassee, FL. Map series; no. 59.

Roesijadi, G. 2004. *Oysters in the St. Lucie estuary*. Contract No. C-14047. Deliverable 2.3b. Annual Report.

Rogers, S.G, T.E. Targett and S.B. Van Sant. 1984. Fish-nursery use in Georgia salt-marsh estuaries: The influence of springtime freshwater conditions. *Transactions of the American Fisheries Society*, 113:595-606.

Russell, G.M. and B.F. McPherson. 1984. *Freshwater runoff and salinity distribution in the Loxahatchee Estuary, Southeastern Florida, 1980-82*. U.S. Geological Survey, Water-Resources Investigations Report 83-4244.

Savage, T. 1972. *Florida mangroves as shoreline stabilizers*. Florida Department of Natural Resources, Professional Papers No. 19. 46 pp.

Sculley, S. 1995. *West Palm Beach Water Catchment Area Water Conservation Study Technical Memorandum No.2 Water Budget Model*. A report submitted to SFWMD under Contract No. C-6113. West Palm Beach, FL.

Sedberry, G.R. and J. Carter. 1993. The fish community of a shallow tropical lagoon in Belize, Central America. *Estuaries*, 16:198-215.

Sellers, M.A. and J.G. Stanley. 1984. *Species profiles: Life histories and environmental requirements of coastal fishes and invertebrates (North Atlantic) – American Oyster*. U.S. Fish and Wildlife Service FWS/OBS-82/11.23. U.S. Army Corps of Engineers, TREL – 82-4. 15 pp.

Semlitsch, R.D., D.E. Scott, J.H.K. Pechmann and J.W. Gibbons. 1996. In *Long-term studies of vertebrate communities*. Academic Press, Inc.

Serafy, J.E., K.C. Lindeman, T.E. Hopkins and J.S. Ault. 1997. Effects of freshwater canal discharge on fish assembladges in a subtropical bay: Field and laboratory observations. *Marine Ecology Program Series*, 160:161-172.

Sheaves, M. 1996. Do spatial differences in the abundance of two serrraind fishes in estuarines of tropical Australia reflect long-term salinity patterns? *Marine Ecology Program Series*, 137:39-49.

Sheng, Y.P. 1986. *CH3D: A three-dimensional numerical model of coastal and estuarine circulation and transport in generalized curvilinear girds*. Technical Report No. 587, Aeronautical Research Associates of Princeton, Inc. NJ.

Shenker, J.M., D.J. Hepner, P.E. Frere, L.E. Currence and W.W. Wakefield. 1983. Upriver migration and abundance of naked goby (*Gobiosoma bosci*) larvae in the Patuxent River estuary, Maryland. *Estuaries,* 6:35-42.

Shenker et al. 1984.

Smith, K.G. 2005. Effects of nonindigenous tadpoles on native tadpoles in Florida: Evidence of competition. *Biological Conservation,* 123:433-441.

Smith, R.D. 1996. Composition, structure, and distribution of woody vegetation on the Cache River floodplain, Arkansas. *Wetlands*, 16(3):264-278.

Sogard, S.M., G.V.N. Powell and J.G. Holmquist. 1989. Utilization by fishes of shallow, seagrass-covered banks in Florida Bay: I. Species composition and spatial heterogeneity. *Environmental Biology of Fishes*, 24:53-65.

Sokal, R.R. 1965. Statistical methods in systematics. *Biological Review (Cambridge),* 40:337-391.

South Florida Water Management District. 2000. *Lower East Coast regional water supply plan*, Water Supply Planning and Development Department, SFWMD, West Palm Beach, FL.

South Florida Water Management District. 2002a. *Northern Palm Beach County comprehensive water management plan*. Final Draft. Water Supply Department, Water Resources Management, SFWMD, West Palm Beach, FL. 2 vols.

South Florida Water Management District. 2002b. *Technical documentation to support development of minimum flows and levels for the Northwest Fork of the Loxahatchee River.* Water Supply Department, SFWMD, West Palm Beach, FL.

South Florida Water Management District. 2004. *Draft document. Chapter X. Salinity measurements and modeling in the Northwest Fork, Loxahatchee River*. Water Supply Department, SFWMD, West Palm Beach, FL.

Southwest Florida Water Management District. 2002. *Upper Peace River: An analysis of minimum flows and levels*. Water Supply Department, SWFWMD, Brooksville, FL.

Spellerberg, I.F. 1991. *Monitoring ecological change*. Cambridge University Press, Cambridge, UK.

Spellerberg, I.F. 1992. *Evaluation and assessment for conservation*. Chapman and Hall, London.

Springer, V.G. and A.J. McErlean. 1961. Spawning seasons and growth of the code goby, *Gobiosoma robustum* (Pisces: Gobiidae), in the Tampa Bay area. *Tulane Studies in Zoology*, 9(2):87-98.

St. Johns River Water Management District and South Florida Water Management District. 2002. *Indian River Lagoon surface water improvement and management plan.* 187 pp. plus figures.

State Organization for Boating Access. 1996. *Design handbook for recreational boating and fishing facilities*.

Stevens, D.E. and L.W. Miller. 1983. Effects of river flow on abundance of young chinook salmon, American shad, longfin smelt, and delta smelt in the Sacramento-San Joaquin River system. *North American Journal Fisheries Management,* 3:425-437.

Stone, M.L., M.R. Whiles, J.A. Webber, K.W.J. Williard and J.D. Reeve. 2005. Macroinvertebrate communities in agriculturally impacted southern Illinois streams: Patterns with riparian vegetation, water quality and in-stream habitat quality. *Journal of Environmental Quality,* 34:907-917.

Strathmann, R.R., T.P. Hughes, A.M. Kuris, K.C. Lindeman, S.G. Morgan, J.M. Pandolfi and R.R. Warner. 2002. Evolution of local recruitment and its consequences for marine populations. *Bulletin of Marine Science*, 70(1):377-396.

Strom, D. and H. Rudolph. 1990. *A macroinvertebrate and water quality survey of the freshwater portion of the Northwest Fork of the Loxahatchee River in Palm Beach and Martin Counties, Florida, in January 1989.* A special monitoring project. Florida Department of Environmental Regulation. Port St. Lucie, FL.

Taylor, R.G., H.J. Grier and J.A. Whittington. 1998. Spawning rhythms of common snook in Florida. *Journal of Fish Biology*, 53:502-520.

Taylor, R.G., J.A. Whittington, H.J. Grier and R.E. Crabtree. 2000. Age, growth, maturation and protandric sex reversal in common snook, *Centropoomus undecimalis*, from the east and west coasts of south Florida. *Fisheries Bulletin*, 98:612-624.

Tennessee Valley Authority. 2004. Dams and Water Quality. Environmental Website, TVAKids.com, 3 pages.

Thayer, G.W., W.J. Kenworthy and M.S. Fonseca. 1984. *The ecology of eelgrass meadows of the Atlantic coast: A community profile*. U.S. Fish and Wildlife Service USFWS/OBS-84/02. 148 pp.

Toth, L.A., S.L. Melvin, D.A. Arrington and J. Chamberlain. 1998. Hydrologic manipulations of the channelized Kissimmee River. *Bioscience* 48:757-764.

Treasure Coast Regional Planning Council. 1999. *Loxahatchee River Basin wetland planning project for Palm Beach County*. Final Report to EPA, Atlanta, GA.

Trexler, J.C. 1995. Restoration of the Kissimmee River: a conceptual model of past and present fish communities and its consequences of evaluating restoration success. Restoration Ecology. 3:195-210.

Turner, J.L. and H.K. Chadwick. 1972. Distribution and abundance of young-of-the-year striped bass, *Morone saxatilis*, in relation to river flow in the Sacramento-San Joaquin Estuary. *Transaction of the American Fisheries Society*, 101:442-452.

U.S. Army Corps of Engineers. 1966a. *Survey report on Jupiter Inlet, Florida: Memorandum report*. USACE, Jacksonville, FL.

U.S. Army Corps of Engineers. 1996b. *User's guide to RMA2 Version 4.3.* U.S. Army Corps of Engineers, Waterways Experiment Station, Hydraulic Laboratory.

U.S. Department of Agriculture, Forest Service. 1965. *Silvics of forest trees of the United States.* H.A. Fowells, comp. U.S. Department of Agriculture, Agriculture Handbook 271. Washington, DC. 762 pp.

U.S. Department of Agriculture, Forest Service. 1974. *Seeds of woody plants in the United States*. C.S. Schopmeyer, Tech. Coord. U.S. Department of Agriculture, Handbook 450. Washington, DC. 883 pp.

U.S. Department of Agriculture, Soil Conservation Service. 1978. *Soil survey of Palm Beach County Area, Florida*.

U.S. Department of Commerce, Nation Oceanic and Atmospheric Administration. National Marine Fisheries Service. Office of Protected Resources. 1998. Endangered Species Act Biennial Report to Congress, October 1, 1996-September 30, 1998.

U.S. Department of Commerce, Nation Oceanic and Atmospheric Administration. National Marine Fisheries Service. Office of Protected Resources. 2000. Endangered Species Act Biennial Report to Congress, October 1, 1998-September 30, 2000.

U.S. Department of Commerce, Nation Oceanic and Atmospheric Administration. National Marine Fisheries Service. Office of Protected Resources. 2002. Endangered Species Act Biennial Report to Congress, October 1, 2000-September 30, 2002.

U.S. Department of Interior, Fish and Wildlife Service. 1996. *Florida manatee recovery plan*. U.S. Fish and Wildlife Service; Atlanta, GA.

U.S. Department of Interior, Fish and Wildlife Service. 1999. *South Florida Multi-species recovery plan -- An ecosystem approach*. Southeast Region, Atlanta, GA. 2172 pp.

U.S. Department of Interior, National Park Service. 1984. *Final Wild and Scenic River Study, Environmental Impact Statement, Loxahatchee River Florida*. U.S. Department of Interior/National Park Service, Atlanta, GA.

U.S. Environmental Protection Agency. 1987. *Estuary Program Primer*, Environmental Protection Agency, Office of Marine and Estuarine Protection, Washington, DC.

U.S. Environmental Protection Agency. 2000. *Evaluation guidelines for ecological indicators*. Office of Research and Development, Washington, DC. EPA/620/R-99/005.

U.S. Geological Survey. 1993. *Hydrology, vegetation, and soils of four north Florida river floodplains with an evaluation of state and federal wetland determinations*, by H.M. Light, M. Darst, M. MacLaughlin and S. Sprecher, Water-Resources Investigation Report 93-4033, 94 pp.

U.S. Geological Survey. 2002. *Ground-cover vegetation in wetland forests of the lower Suwannee River floodplain, Florida, and potential impacts of flow reductions*, by M.R. Darst, H.M. Light and L.J. Lewis, Water-Resources Investigation Report 02-4027, 46 pp.

U.S. Geological Survey. 2002. *Location and description of transects for ecological studies in floodplain forests of lower Suwannee River, Florida,* by L.J. Lewis, H.M. Light and M.R. Darst, Open-File Report 01-410, 83 pp.

U.S. Geological Survey. 2004 unpublished. *Assessment of groundwater input and biogeochemical characteristics in the Loxahatchee River and floodplain ecosystem*, Tampa, FL.

Virnstein, R.W., P.S. Mikkelsen, K.D. Cairns and M.A. Capone. 1983. Seagrass beds versus sand bottoms: The trophic importance of their associated benthic invertebrates. *Florida Scientist*, 46:363-381.

Volety, A.K., S.G. Tolley and J.T. Winstead. 2003. *Effects of seasonal and water quality parameters on oysters (Crassostrea virginica) and associated fish populations in the Caloosahatchee River.* Final Report to South Florida Water Management District. Contract: C-12412-A1.

Wallin, J.E., J.M. Ransier, S. Fox and R.H. McMichael, Jr. 1997. Short-term retention of coded wire and internal anchor tags in juvenile common snook, *Centropomus undecimalis*. *Fisheries Bulletin*, 95:873-878.

Wan, Y., C. Reed and E. Roaza. 2003. Modeling watersheds with high groundwater tables and dense drainage canals. *Proceedings of 2003 AWRA International Congress: Watershed Management for Water Supply*. New York, p. 10.

Ward and Roberts, 1993-94. Please provide more information such as a title and status of publication

Ward, T.H. and R.E. Roberts. 1996. *Vegetation analysis of the Loxahatchee River corridor* (unpublished draft). Florida Department of Environmental Protection/Jonathan Dickinson State Park, Hobe Sound, FL. 60 pp.

Ward, L.G., W.M. Kemp and W.R. Boynton. 1984. The influence of waves and seagrass communities on suspended particles in an estuarine embayment. *Marine Geology* 59:85-103.

Washington State Department of Ecology. 2004. *Water quality certifications for existing hydropower dams: Guidance manual*. No. 04-10-022, 60 pages.

Weinstein, M.P., S.L. Weiss, R.G. Hodson and L.R. Gerry. 1980. Retention of three taxa of postlarval fishes in an intensively flushed tidal estuary, Cape Fear River, North Carolina. *U.S. Fisheries Bulletin*, 78:419-436.

Wells, H.W. 1961. The fauna of oyster beds, with special reference to the salinity factor. *Ecological Monographs*, 31:239-266.

Wharton, C.H., W.M. Kitchens, E.C. Pendleton and T.W. Sipe. 1982. *The ecology of bottomland hardwood swamps of the southeast:A community profile*. U.S. Fish and Wildlife Service, Washington DC. FWSIOBS-81/37.

Whitfield, A.K. and M.N. Bruton. 1989. Some biological implications of reduced freshwater inflow into eastern Cape estuaries: A preliminary assessment. *South African Journal of Science*, 85:691-694.

Wicker, K.M., D. Davis, M. DeRouen and D. Roberts. 1981. *Assessment of extent and impact of saltwater intrusion into the wetlands of Tangipahoa Parish, Louisiana*. Coastal Environments Inc. Baton Rouge, LA. 59 pp.

WildPine Ecological Laboratory. 2004. *Loxahatchee River estuary live oyster location mapping 2003 report.*

Wilson, C., L. Scotto, J. Scarpa, A. Volety, S. Laramore and D. Haunert. 2004 (in press). Survey of water quality, oyster reproduction and oyster health status in the St. Lucie Estuary. *Florida Scientist*.

Winans, 1990. Fish marking techniques. *American Fisheries Society Symposium No. 7*. Bethesda, MD, USA. 879 pp.

Winemiller, K.O. 1983. An introduction to the freshwater fish communities of Corcovado National Park, Costa Rica. *Brenesia*, 21:47-66.

Winemiller, K.O. and N.E. Morales. 1989. Comuniddaes de peces del Parque Nacional Corcovado luego del cese de las actividades mineras. *Brenesia*.

Winemiller, K.O. and B.J. Ponwith. 1998. Comparative ecology of eleotrid fishes in Central American coastal streams. *Environmental Biology of Fishes*, 53:373-384.

Woodward-Clyde International-Americas. 1998. *St. Lucie Estuary Historical, SAV, and American Oyster Literature Review, Final Report.* Woodward-Clyde International-Americas, Tallahassee, Florida. Contract C-7779. Prepared for the South Florida Water Management District. West Palm Beach, FL.

Worth, D. 1983-1984. *Vegetation and groundwater studies on the Northwest Fork of the Loxahatchee River and Cypress Creek*. Unpublished internal report. South Florida Water Management District, West Palm Beach, FL.

Worth, 1984. Please provide more information such as a title and status of publication

Worth, D. 1986. *Loxahatchee River vegetation and groundwater study*. Unpublished internal report. South Florida Water Management District, West Palm Beach, FL.

Wright, S.J., Gompper, M.E. and Deleon, B. 1994. Are large predators keystone species in neotropical forests? The evidence from Barro Colorado Island. *Oikos*, 71(2):279–294.

Yahner, R.H. and Smith, H.R. 1991. Small mammal abundance and habitat relationships on deciduous forested sites with different susceptibility to gypsy moth defoliation. *Environmental Management*, 15(1):113–120.

Yanez-Arancibia, A. Editor. 1985. *Fish community ecology in estuaries and coastal lagoons*. Univ. Nacional Autonoma de Mexico, Ciudad Universitaria, Mexico, D.F. 653 pp.

Zahina, J.G. 2004. *Vegetation community characteristics along the Northwest Fork of the Loxahatchee River and development of a salinity-vegetation model*. SFWMD Technical Publication, WS-19.

Zieman, J.C. 1982. *The ecology of the seagrasses of south Florida: A community profile*. U.S. Fish and Wildlife Service. FWS/OBS-82/25, 158 pp.

Zieman, J.C. and R.T. Zieman. 1989. *The ecology of the seagrass meadows of the west coast of Florida: A community profile.* U.S. Fish and Wildlife Service Biological Report. 85(7.25). 155 pp.

Appendix A

2003 Vegetation Survey –

Forest Type Summaries

Table A-1. Transect #1 (NW01; RM 14.7) Forest Types for Each 10m X 10m Plot Based on Relative Basal Area (RBA).

Plot #	Forest Type		Plot #	Forest Type
1 (T 1-1)	Mesic Hammock		10 (T 1-2)	Rblh1
2	Mesic Hammock		11	Rsw1
3	Upland/Mesic Hammock		12	Rsw1
4	Hydric Hammock		13	Rsw1
5	Rsw1		14	Rsw1
6	Rsw1		15	Hydric Hammock
7	Rsw1			
8	Rsw1			
9	Rsw1			

Table A-2. Transect #2 (NW02; RM 13.5) Forest Types for Each 10m X 10m Plot Based on Relative Basal Area (RBA).

Plot #	Forest Type		Plot #	Forest Type
16 (T 2-1)	Rblh1		23 (T 2-2)	Mesic Hammock
17	Rsw1		24	Mesic Hammock
18	Hydric Hammock/Rsw1		25	Mesic Hammock
19	Rsw1		26	Hydric Hammock/Rsw1
20	Hydric Hammock/Rsw2		27	Rsw1
21	Hydric Hammock		28	Rsw2
22	Hydric Hammock			

Table A-3. Transect #3* (NW03; RM 12.1) Forest Types for Each 10m X 10m Plot Based on Relative Basal Area (RBA).

Plot #	Forest Type		Plot #	Forest Type
29 (T 3-1)	Rblh2		40 (T 3-2)	Upland/Mesic Hammock
30	Rblh3		41	Rblh2
31	Rsw2			
32	Rsw2			
33	Rsw2			
34	Rsw2			
35	Rsw2			
36	Rsw1			
37	Rsw2			
38	Rsw2			
39	Rsw2			
* Selective logging occurred in this area.				

Table A-4. Transect #4 (NW04; RM 11.18) Forest Types for Each 10m X 10m Plot Based on Relative Basal Area (RBA).

Plot #	Forest Type
42 (T 4-1)	Mesic Hammock
43	Rsw1
44	Rsw1
45	Rblh2
46	Rsw1
47	Rsw1
48	Rsw1
49	Rblh2
50	Rblh3
51	Rsw2
52	Rsw1
53	Rblh2

Table A-5. Transect #6* (NW06; RM 8.4) Forest Types for Each 10m X 10m Plot Based on Relative Basal Area (RBA).

Plot #	Forest Type
68 (T 6-1)	Upland
69	Hydric Hammock
70	Rsw1
71	UTsw3
72	UTsw3
73	UTsw3
74	UTsw3
75	UTsw3
76	UTmix
77	UTsw1
78	UTsw1
79	UTsw1
80	UTsw1
81	UTsw3
82	UTsw1
83	UTsw1
* Selective logging occurred in this area.	

Table A-6. Transect #7* (NW07; RM 9.1) Forest Types for Each 10m X 10m Plot Based on Relative Basal Area (RBA).

Plot #	Forest Type
84 (T 7-1)	Hydric Hammock/Rsw1
85	Rsw1
86	Rsw1
87	Rmix
88	Rmix
89	Rmix
90	Rmix
91	Rmix
92	UTsw1
93	UTsw1
94	UTsw1
95	UTsw1
96	UTsw2
97	UTsw2
98	UTsw2
* Selective logging occurred in this area.	

Table A-7. Transect #9 (NW09; RM 6.46) Forest Types for Each 10m X 10m Plot Based on Relative Basal Area (RBA).

Plot #	Forest Type
111 (T 9-1)	Upland
112	Hydric Hammock
113	LTsw2
114	LTsw2
115	LTsw2
116	LTmix
117	LTsw2
118	LTsw2
119	LTsw2
120	LTsw2
121	LTsw2
122	LTsw2
123	LTsw2
124	LTsw2
125	LTsw2
126	LTsw2
127	LTsw1
128	LTsw1
129	LTsw1
130	LTsw1

Appendix B

2003 Vegetation Survey –

Forest Canopy Species by Transect

Table B-1. 2003 Vegetation Survey Canopy Plant List and Code List.

Scientific Name	Common Name	Code Name
Acer rubrum	Red maple	**AR**
Annona glabra	Pond apple	**AG**
Carya aquatica	Water hickory	**CA**
Cephalanthus occidentalis	Buttonbush	**CO**
Chrysobalanus icaco	Cocoplum	**CI**
Citrus sp.	--	**CS**
Ficus aurea	Strangler ficus	**FA**
Fraxinus caroliniana	Pop ash	**FC**
Ilex cassine	Dahoon holly	**IC**
Laguncularia racemosa	White mangrove	**LR**
Myrica cerifera	Wax myrtle	**MC**
Persea borbonia	Red Bay	**PB**
Persea palustris	Swamp bay	**PP**
Pinus elliottii	Slash pine	**PE**
Psidium cattleianum	Strawberry guava	**PC**
Quercus laurifolia	Laurel oak	**QL**
Quercus myrtifolia	Myrtle oak	**QM**
Quercus virginiana	Live oak	**QV**
Rhizophora mangle	Red mangrove	**RM**
Roystonea regia	Royal palm	**RR**
Sabal palmetto	Cabbage palm	**SP**
Salix caroliniana	Carolina willow	**SaC**
Schinus terebinthifolius	Brazilian pepper	**ST**
Syzgium cumini	Java plum	**SC**
Taxodium distichum	Bald cypress	**TD**

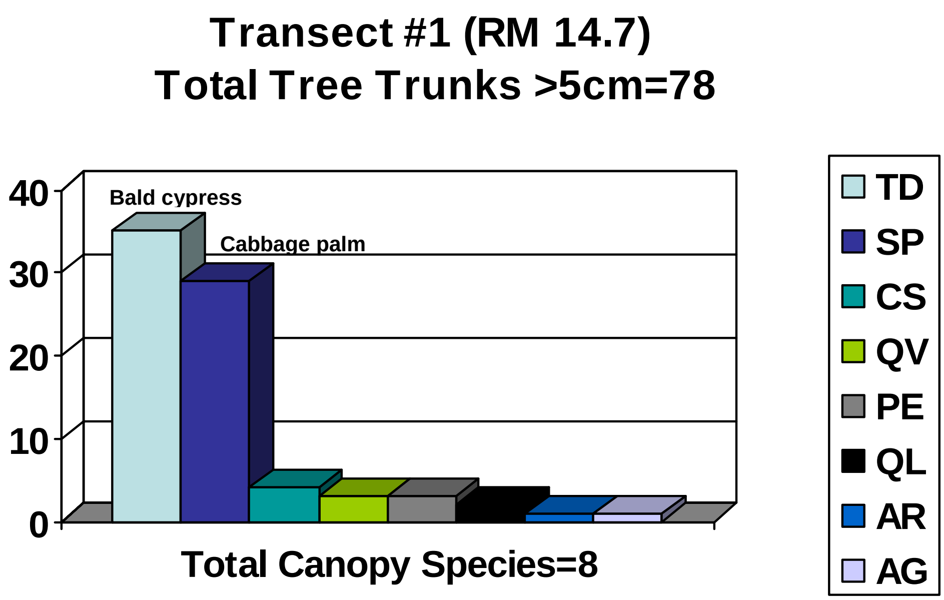


Figure B-1. Transect #1 - Number of Trunks (> 5cm) by Canopy Species.

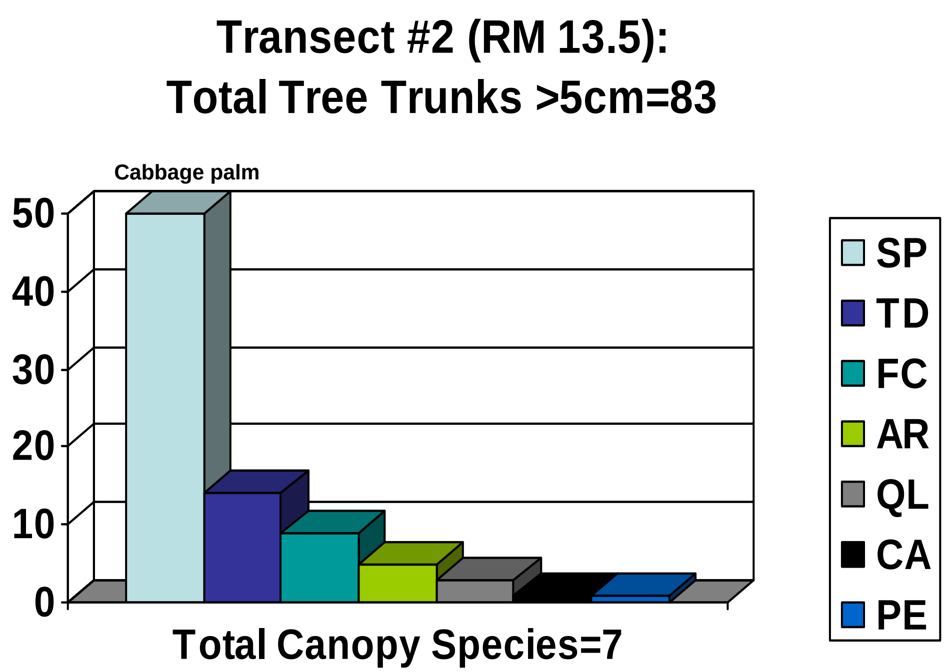


Figure B-2. Transect #2 - Number of Trunks (> 5cm) by Canopy Species.

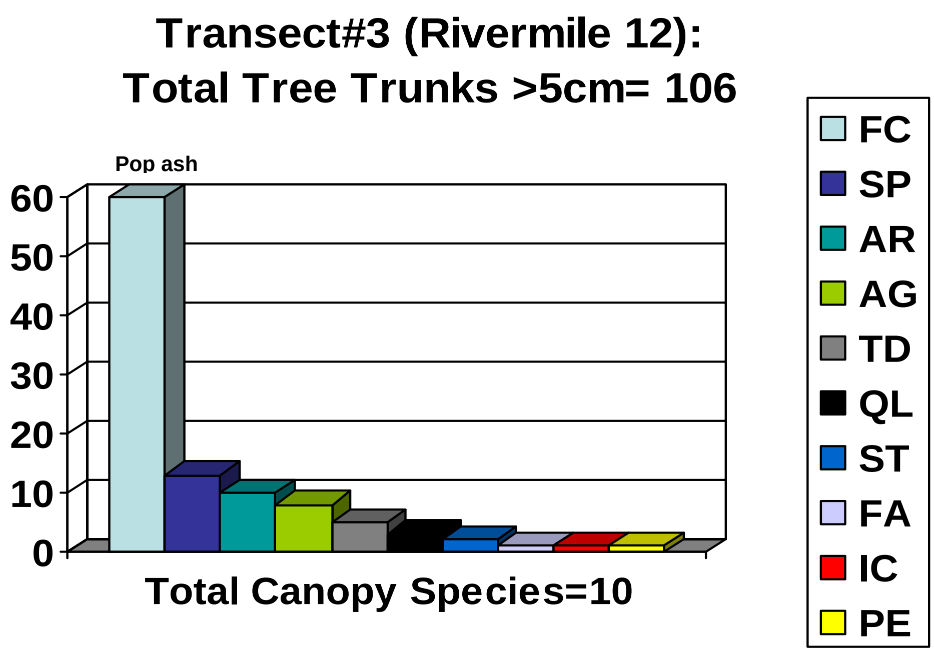


Figure B-3. Transect #3 - Number of Trunks (> 5cm) by Canopy Species.

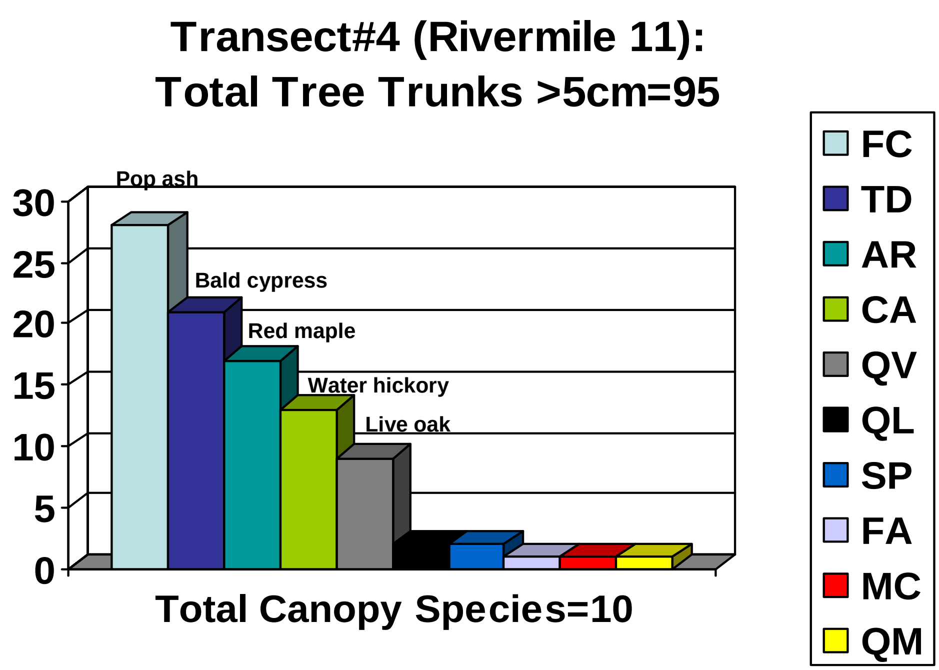


Figure B-4. Transect #4 - Number of Trunks (> 5cm) by Canopy Species.

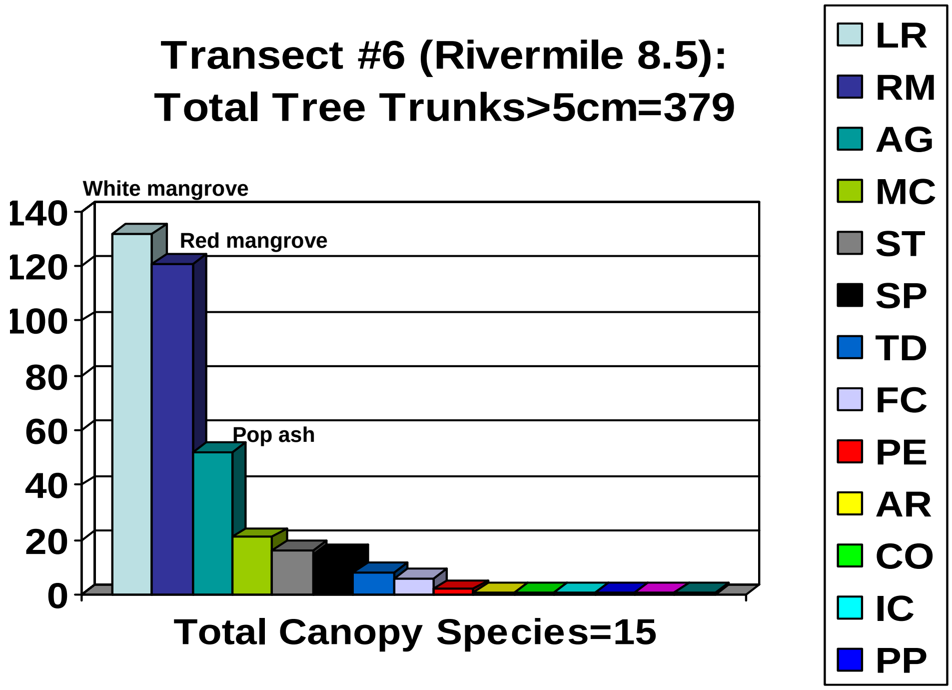


Figure B-5. Transect #6 - Number of Trunks (> 5cm) by Canopy Species.

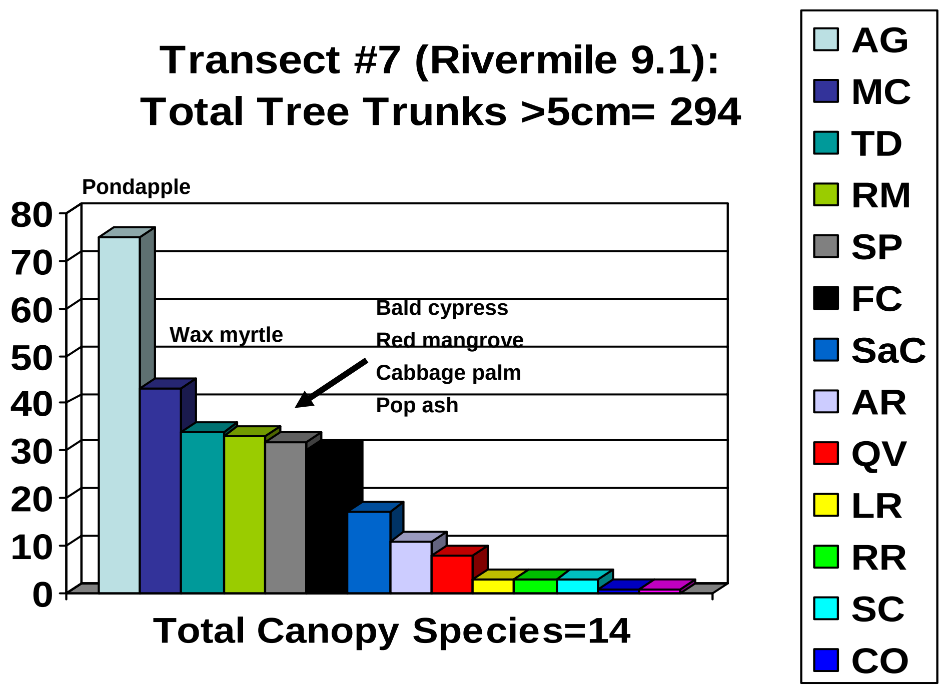


Figure B-6. Transect #7 - Number of Trunks (> 5cm) by Canopy Species.

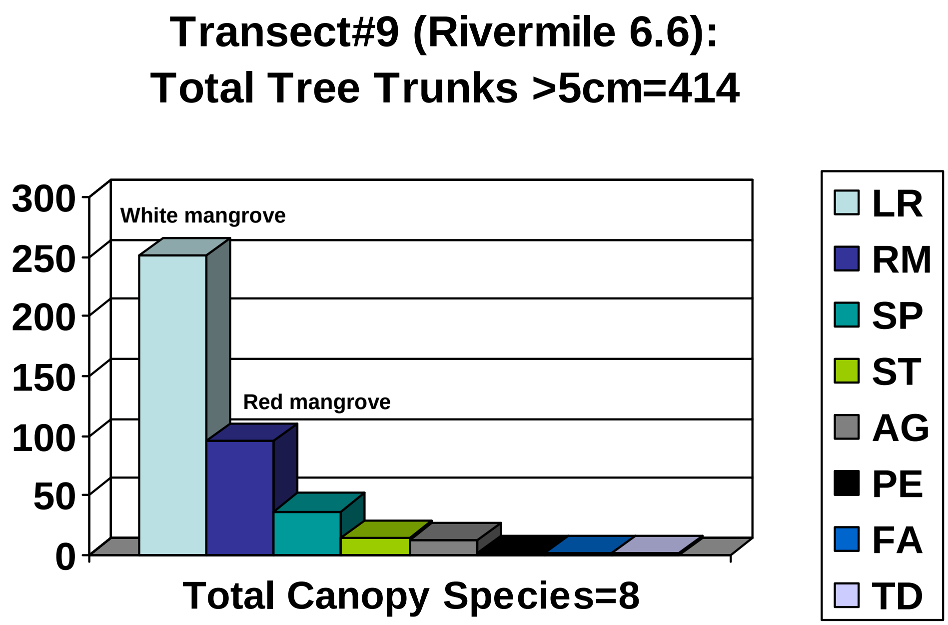


Figure B-7. Transect #9 - Number of Trunks (> 5cm) by Canopy Species.

Appendix C

2003 Vegetation Survey –

Transect Profiles

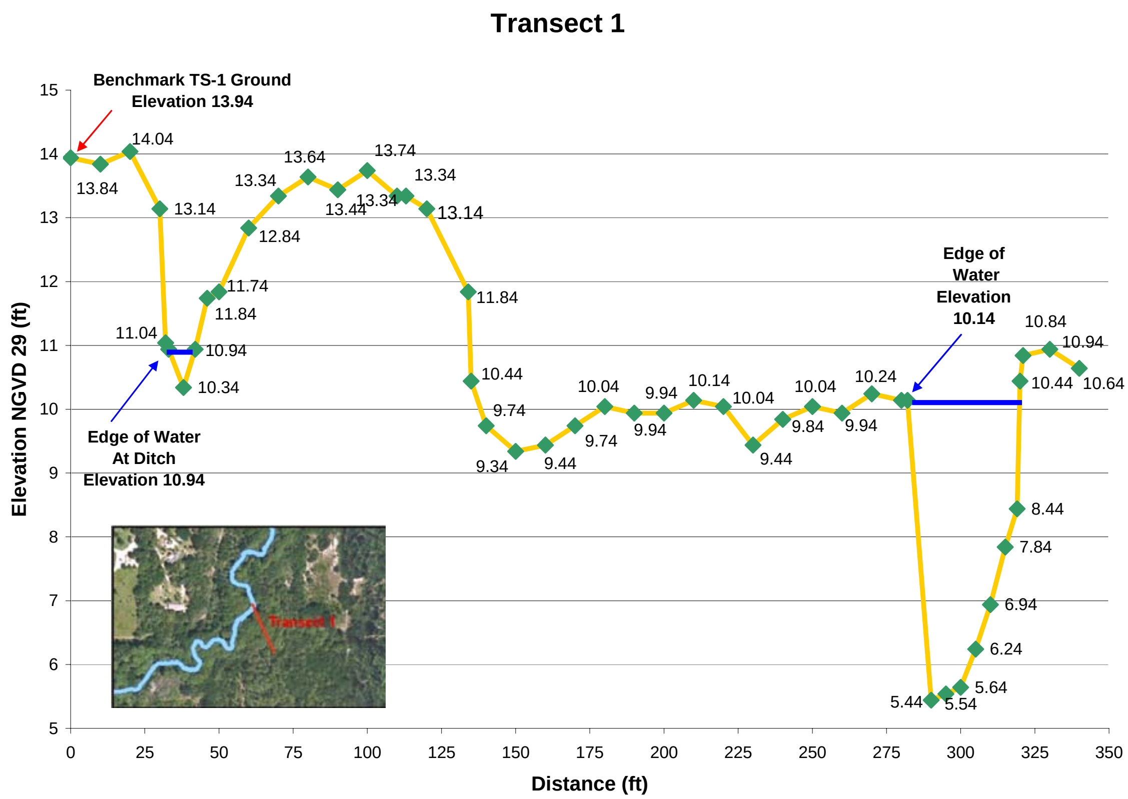


Figure C-1. Transect #1 (RM 14.5) Profile.

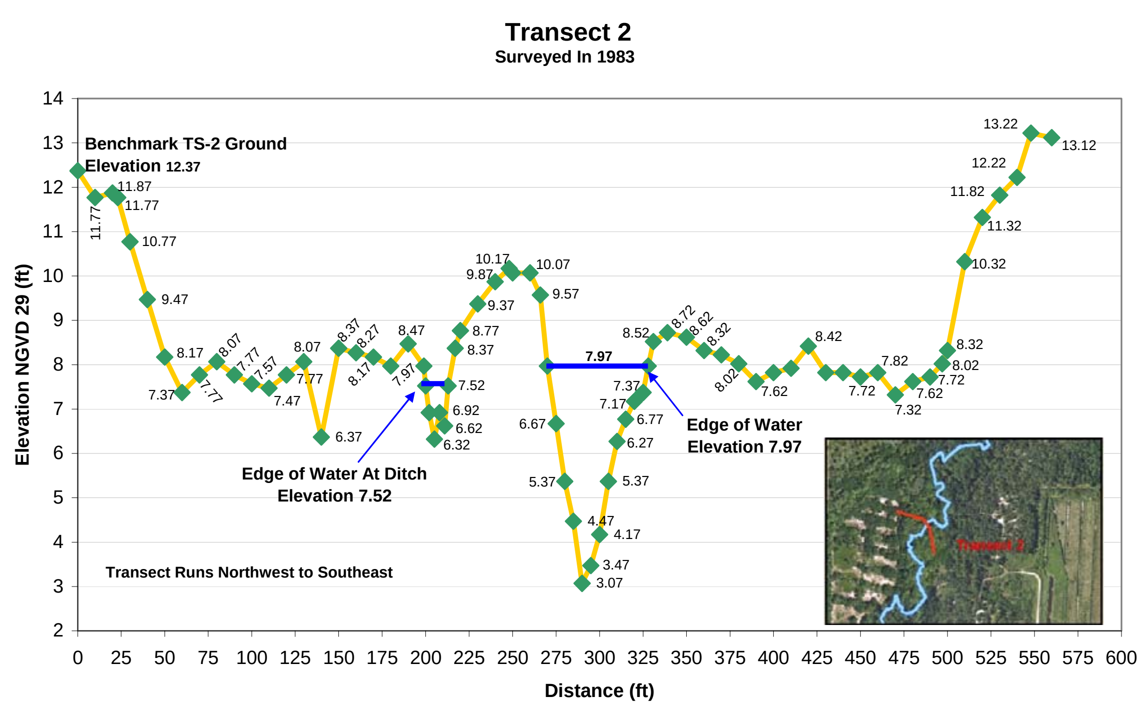


Figure C-2. Transect #2 (RM 13.5) Profile.

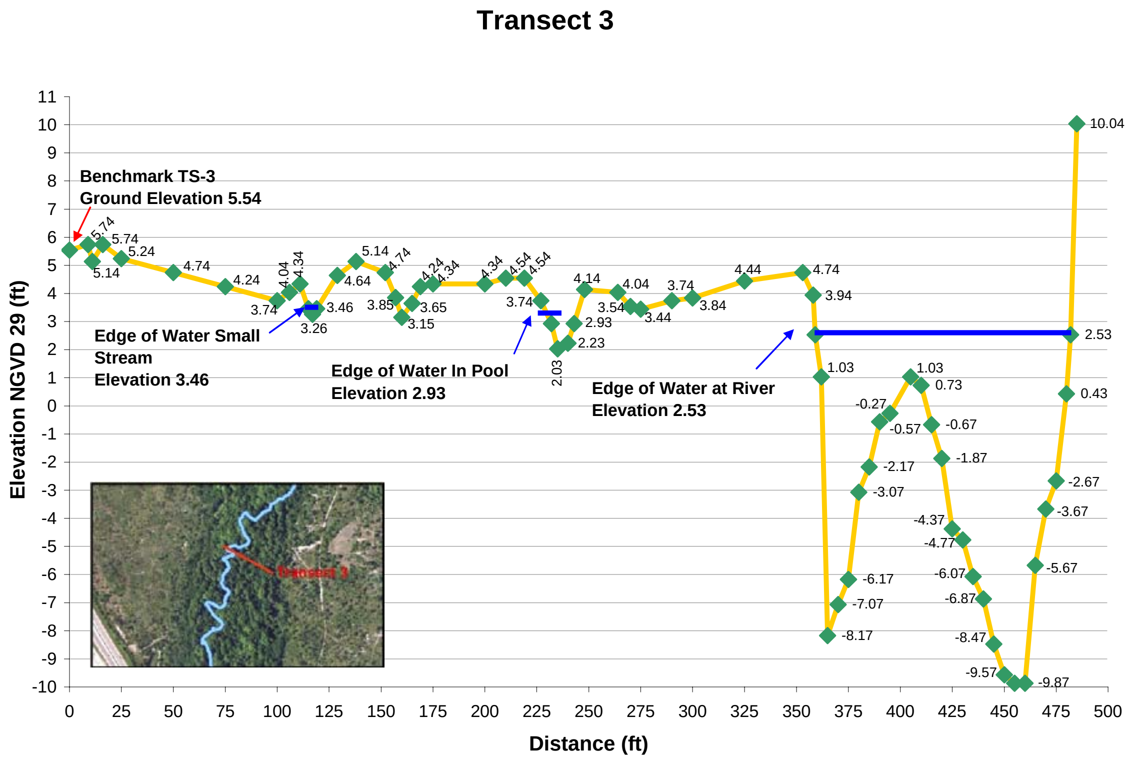


Figure C-3. Transect #3 (RM 12.1) Profile.

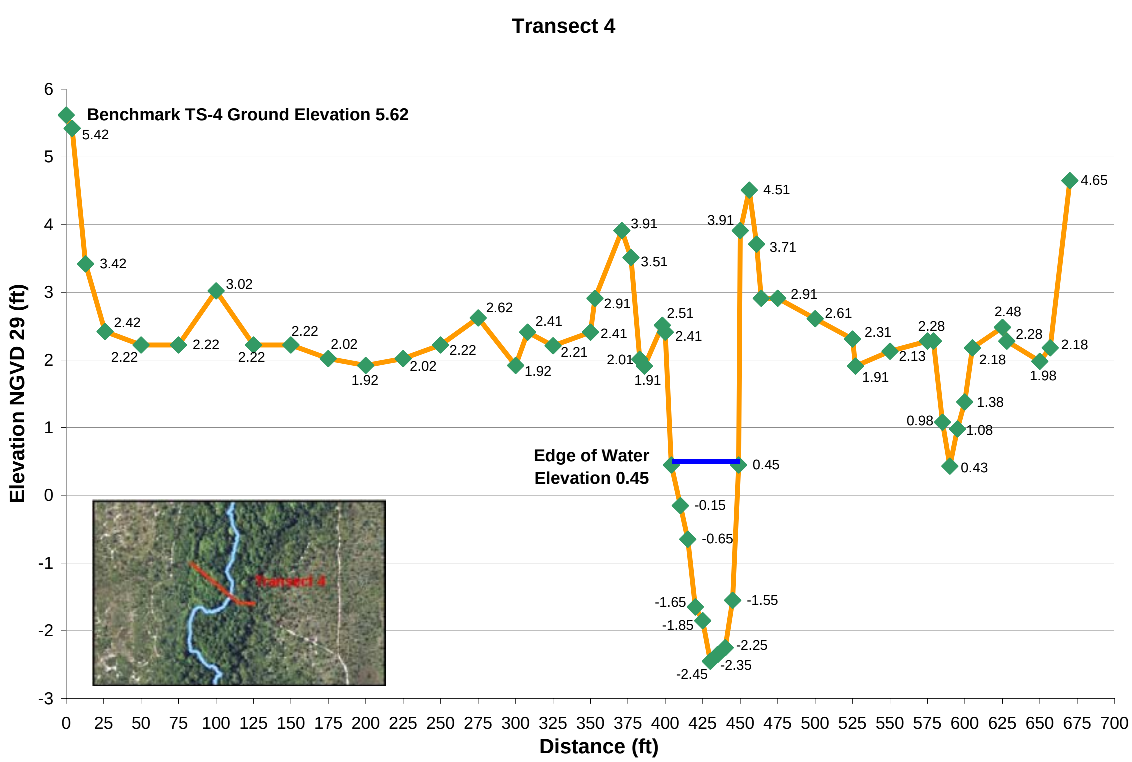


Figure C-4. Transect #4 (RM 11.18) Profile.

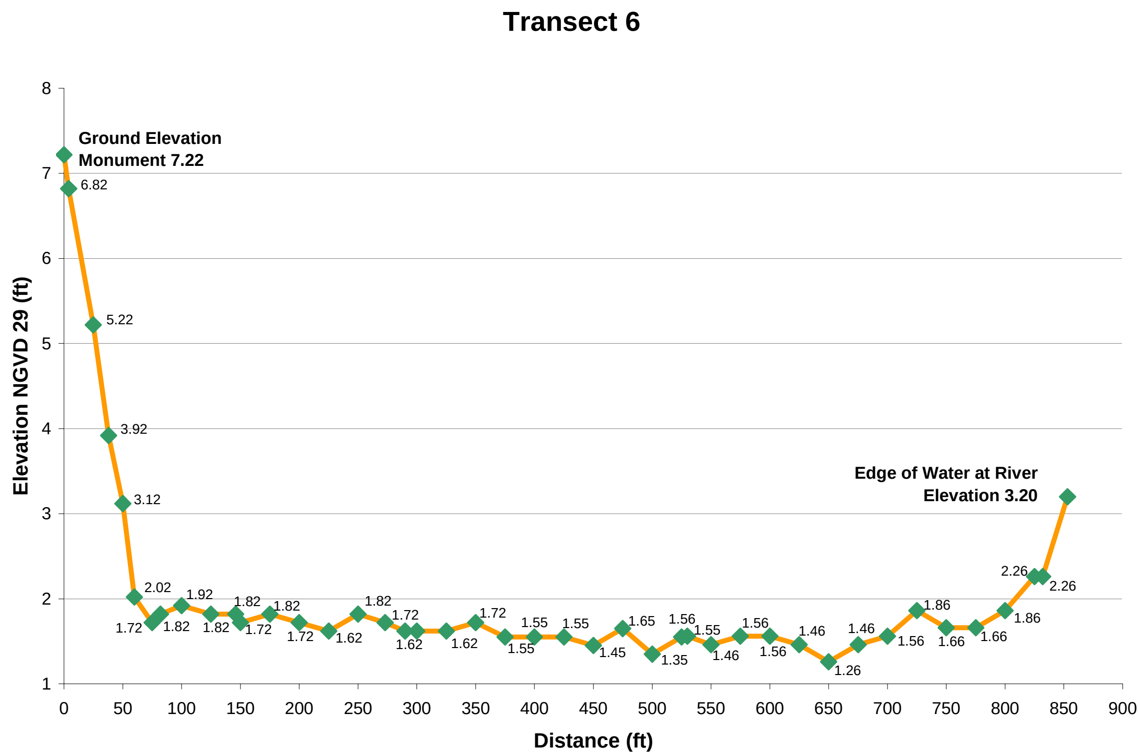


Figure C-5. Transect #6 (RM 8.4) Profile.

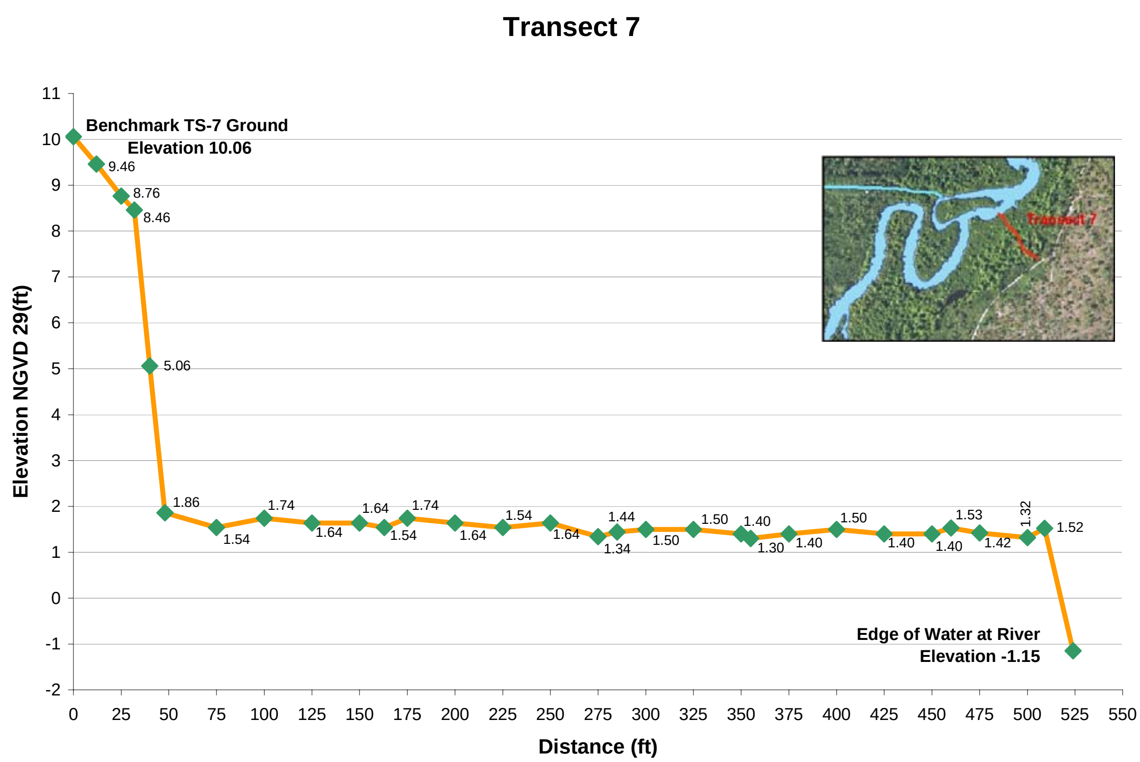


Figure C-6. Transect #7 (RM 9.1) Profile.

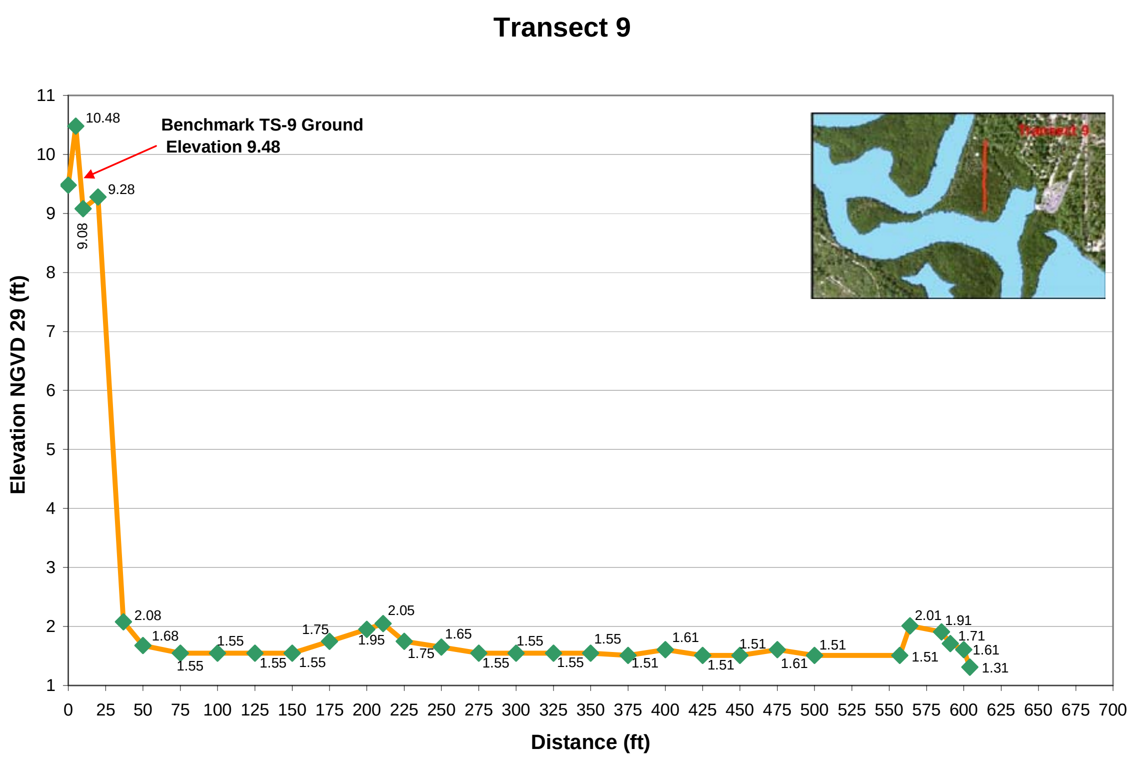


Figure C-7. Transect #9 (RM 6.46) Profile.

Appendix D

Vegetation Transects Groundwater and Soils Characteristics

Table D-1. Transect #1 Soils Characteristics and Groundwater Depth.

Sample ID	Depth (cm)	Length, transect (m)	Soil name	Soil description (cm)	Horizon (cm)	Water table depth (cm)
T1-1-20	0-20	25	Riviera Series	0-15cm:10YR3/1, fine sand with many uncoated sand grains; 15-20: 10YR5/1 fine sand	0-15: A horizon; 15-60: E1 horizon	>120
T1-1-40	20-40	25	Riviera Series	15-60: 10YR5/1 fine sand	Same as above	>120
T1-1-60	40-60	25	Riviera Series	Same as above	Same as above	>120
T1-1-80	60-80	25	Riviera Series	60-90: 10YR7/1 fine sand	60-90: E2	>120
T1-1-100	80-100	25	Riviera Series	90-120: 10YR4/3 sandy clay loam	90-120: Bt layer	>120
T1-1-120	100-120	25	Riviera Series	Same as above	Same as above	>120
T1-2-20	0-20	65	Fluvaquent	0-30: 5Y2.5/1 clay w/ C2D 10Y5/6 mottles		>120
T1-2-40	20-40	65	Fluvaquent	same as above to 30; 30-50: 5Y3/1 Sandy Clay		>120
T1-2-60	40-60	65	Fluvaquent	same as above to 50; 50-60: change to fine sand, 2.5Y5/2		>120
T1-2-80	60-80	65	Fluvaquent	10YR8/1 fine sand		>120
T1-2-100	80-100	65	Fluvaquent	10YR3/2 loamy sand		>120
T1-2-120	100-120	65	Fluvaquent	Same as above		>120
T1-3-20	0-20	25 (?)		0-22: 5Y3/1 sandy clay loam		100
T1-3-40	20-40	25 (?)		22-45: white sand		100
T1-3-60	40-60	25 (?)		45-100+: change to grey loamy fine sand, 5Y3/1		100
T1-3-80	60-80	25 (?)		Same as above		100
T1-3-100	80-100	25 (?)		Same as above		100
T1-3-120	100-120	25 (?)				100
T1-4-20	0-20	55(?)		10YR4/1 fine sand		110
T1-4-40	20-4	55(?)		20-50:10YR5/3 fine sand		110
T1-4-60	40-60	55(?)		50-90: same as above getting loamier, sandy loam		110
T1-4-80	60-80	55(?)		Same as above		110
T1-4-100	80-100	55(?)		90-120: loamy sand w/ common shell fragments, 5Y7/1		110
T1-4-120	100-120	55(?)		Same as above		110

Samples collected May 20, 2004.
Data from “Soils Survey of the Loxahatchee River Floodplains,” by Li et al., University of Florida, Gainesville.

Table D-2. Transect #2 Soils Characteristics and Groundwater Depth.

Sample ID	Depth (cm)	Length, transect (m)	Soil name	Soil description (cm)	Horizon (cm)	Water table depth (cm)
T2-1-20	0-20	0-5	unknown	0-10: 10YR3/1 fine sand with many uncoated sand grains; 10-20: 10YR2/2 fine sand	10:Bh (no E)	>120
T2-1-21	20-40	0-5	unknown	Same as above to 30 30-60: 10YR5/4 color change	30: E horizon	>120
T2-1-22	40-60	0-5	unknown	Same as above	E horizon	>120
T2-1-23	60-80	0-5	unknown	10YR6/3 fine sand	E horizon	>120
T2-1-24	80-100	0-5	unknown	80-90: 5Y5/1 sandy clay loam with few fine F1P7.5YR5/8 mottles (red); 90-100:10YR5/2 loamy sand		>120
T2-1-25	100-120	0-5	unknown	Same as above to 110 110-120: 10YR5/2 sandy loam		>120
none	>120	0-5	unknown	10YR3/3 sand		>120
T2-2-20	0-20	55-65	unknown	5Y2.5/1 Sapporic Muck	0-30: A horizon	120
T2-2-40	20-40	55-65	unknown	Same as above to 30 30-40: 5Y4/1 sandy clay loam		120
T2-2-60	40-60	55-65	unknown	sandy clay loam, lighter in texture		120
T2-2-80	60-80	55-65	unknown	5Y5/1 sandy loam, sandier.		120
T2-2-100	80-100	55-65	unknown	5Y5/1sand		120
T2-2-120	100-120	55-65	unknown	same		120
none	>120	55-65	unknown	sandy to 204 cm.		120
T2.2-1-20	0-20	5	unknown	0-10: 10YR3/1 fine sand, many uncoated sand grains; 10-40: 10YR6/2 fine sand	AP horizon	>120
T2.2-1-40	20-40	5	unknown	Same as above		>120
T2.2-1-60	40-60	5	unknown	10YR6/3 fine sand		>120
T2.2-1-80	60-80	5	unknown	Same as above	E horizon	>120
T2.2-1-100	80-100	5	unknown	Same as above to 90; 90-100: 10YR6/3 sandy loam with M12D 10YR5/8 mottles and common C2D 10YR6/2 mottles		>120
T2.2-1-120	100-120	5	unknown			>120
none	>120	5	unknown	10YR5/3 sand to >120		
T2.2-2-20	0-20	35-45	unknown	5Y2.5/1 Sapporic muck		100
T2.2-2-40	20-40	35-45	unknown	Same as above		100
T2.2-2-60	40-60	35-45	unknown	Same as above		100
T2.2-2-80	60-80	35-45	unknown	Same as above		100
T2.2-2-100	80-100	35-45	unknown	5Y2.5/1 Sandy loam		100
T2.2-2-120	100-120	35-45	unknown	Same as above		100
none	160-160+	35-45	unknown	10YR6/2 sand		100

Samples collected May 20, 2004.
Data from "Soils Survey of the Loxahatchee River Floodplains," by Li et al., University of Florida, Gainesville.

Table D-3. Transect #3 Soils Characteristics and Groundwater Depth.

Sample ID	Depth (cm)	Length, transect (m)	Soil name	Soil description (cm)	Horizon (cm)	Water table depth (cm)
T3-1-20	0-20	0	possibly Nettles	0:10YR2/1; 7.6: 10YR3/1 to 33cm	0: A layer, 7.6: E layer	none
T3-1-40	20-40	0	possibly Nettles	Same as above to 33 33-40:10YR6/1	33:E2 Layer	none
T3-1-60	40-60	0	possibly Nettles	Same as above to 55 55-60: 10YR3/2	55: Bh	none
T3-1-80	60-80	0	possibly Nettles	Same as above to 75 75-90: 10YR2/1, weakly cemented	75: Bh2	none
T3-1-100	80-100	0	possibly Nettles	Same as above to 90 90-100: change layer type.	90:Bh3	none
	100-120	0	possibly Nettles	100: 10YR5/3; 115: 5YR5/1	100:E' Layer; 115: Btg	none
T3-2-20	0-20	55	Fluvaquent	10YR2/1 stratified sand/sandy clay loam, various texture		100
T3-2-40	20-40	55	Fluvaquent	10YR2/1 Sandy clay loam		100
T3-2-60	40-60	55	Fluvaquent	7.5YR2/0		100
T3-2-80	60-80	55	Fluvaquent	10YR4/2 Sandy texture		100
T3-2-100	80-100	55	Fluvaquent	10YR5/3 Sand		100
	151	55	Fluvaquent	5GY6/1 Sandy clay		100
T3-3-20	0-20	79	Fluvaquent	10YR2/1 Sandy clay		85
T3-3-40	20-40	79	Fluvaquent	Same as above to 35 35-40: change in texture to 10YR3/1 sand		85
T3-3-60	40-60	79	Fluvaquent	10YR3/1 stratified sand and sandy clay		85
T3-3-80	60-80	79	Fluvaquent	Same as above to 70. 70-80: 10YR4/1 sand		85
T3-3-100	80-100	79	Fluvaquent	Sand 10YR7/1		85
T3-3-120	100-120	79	Fluvaquent	Same as above		85
T3-4-20	0-20	105		10YR3/1	A Layer	70
T3-4-40	20-40	105		24: change to 10YR7/2 fine sand matrix with MPP 2.5YR44 iron red mottling		70
T3-4-60	40-60	105		Same as above		70
T3-4-80	60-80	105		Same as above to 70 70-80 :texture change to 10YR7/1 stratified sandy loam / 2.5YR5/0 sand		70
T3-4-100	80-100	105		10YR3/2, still stratification		70
T3-4-120	100-120	105		115: change to 10YR7/1 sand to 120+		70

Samples collected May 20, 2004.
Data from "Soils Survey of the Loxahatchee River Floodplains," by Li et al., University of Florida, Gainesville.

Table D-4. Transect #4 Soils Characteristics and Groundwater Depth.

Sample ID	Depth (cm)	Length, transect (m)	Soil name	Soil description (cm)	Horizon (cm)	Water table depth (cm)
T4-1-20	0-20	5	Smyrna soil	10YR3/1 fine sand with many uncoated sand grains	A layer	>120
T4-1-21	20-40	5	Smyrna soil	10YR4/2 fine sand	E layer	>120
T4-1-22	40-60	5	Smyrna soil	10YR3/2 fine sand	Bh	>120
T4-1-23	60-80	5	Smyrna soil	Same as above	Bh	>120
T4-1-24	80-100	5	Smyrna soil	Same as above to 90 90: 10R4/3 fine sand	C1	>120
T4-1-25	100-120	5	Smyrna soil	100: 10YR5/3 fine sand; 110: 10YR6/2	100: C2; 110: C3	>120
						>120
T4-2-20	0-20	75-85	Fluvaquent	10YR2/1 Sapporic material		106
T4-2-40	20-40	75-85	Fluvaquent	Same as above to 30 30: fine sandy loam.	30: C layer	106
T4-2-60	40-60	75-85	Fluvaquent	Sandy clay loam		106
T4-2-80	60-80	75-85	Fluvaquent	10YR4/1 fine sandy loam with stratified layers of 10YR6/2 sand		106
T4-2-100	80-100	75-85	Fluvaquent	Same as above		106
T4-2-120	100-120	75-85	Fluvaquent	Same as above		106
none	163-204+	75-85	Fluvaquent	10YR7/2 sand, entire column is stratified.		106
T4-3-20	0-20	115		0: 10YR3/1 fine sand with many uncoated sand grains; 6: stratified 7.5YR3/0 fine sandy loam matrix / 10YR6/2 fine sand / and 5YR3/2 sandy clay loam	6: C layer	
T4-3-40	20-40	115		Same as above		
T4-3-60	40-60	115		Same as above		
T4-3-80	60-80	115		Same as above		
T4-3-100	80-100	115		Same as above to 90 90: sandy clay loam stratified with 5YR3/2 sand		
T4-3-120	100-120	115		Same as above		
none	120-204+	115		Alternating layers of sand / sandy clay loam		

Samples collected May 27, 2004.
Data from "Soils Survey of the Loxahatchee River Floodplains," by Li et al., University of Florida, Gainesville.

Table D-5. Transect #6 Soils Characteristics and Groundwater Depth.

Sample ID	Depth (cm)	Length, transect (m)	Soil name	Soil description	Horizon (cm)	Water table depth (cm)
T6-1-20	0-20	5	Nettles sand	10YR31sand, many uncoated sand grains, few accretions	0: A horizon	not found
T6-1-40	20-40	5	Nettles sand	20-30: 10YR42 fine sand; 30-40:10YR52 fine sand, transition to…		not found
T6-1-60	40-60	5	Nettles sand	10YR52 sand		not found
T6-1-80	60-80	5	Nettles sand	10YR62	60: E horizon	not found
T6-1-100	80-100	5	Nettles sand	Same as above to 110		not found
T6-1-120	100-120	5	Nettles sand	110: 10YR43 sand	110: Bh, not typical horizon, not enough organic carbon to be a spodosol	not found
none	204	5	Nettles sand	sandy to 204 cm+		not found
T6-2-20	0-20	26	Terra Ceia Variant	5YR2.5/1 Muck	OA-1	4
T6-2-40	20-40	26	Terra Ceia Variant	5YR2.5/1 Muck	OA-1	4
no sample	204	26	not viewed	no sand layer found	not viewed	4
T6-3-20	0-20	115	Terra Ceia Variant	5YR2.5/1 Muck	OA-1	33
T6-3-40	20-40	115	Terra Ceia Variant	5YR2.5/1 Muck	OA-1	33
T6-3-60	40-60	115	Terra Ceia Variant	5YR2.5/1 Muck	OA-1	33
no sample	204	115	Terra Ceia Variant	Muck 204+, no sand found		33
T6-4-20	0-20	130	Terra Ceia Variant	5YR2.5/1 Muck	OA-1	15
T6-4-40	20-40	130	Terra Ceia Variant			15
T6-4-60	40-60	130	Terra Ceia Variant			15

Samples collected May 20, 2004.
Data from "Soils Survey of the Loxahatchee River Floodplains," by Li et al., University of Florida, Gainesville.

Table D-6. Transect #7 Soils Characteristics and Groundwater Depth.

Sample ID	Depth (cm)	Length, transect (m)	Soil name	Soil description (cm)	Horizon (cm)	Water table depth (cm)
T7-1-20	0-20	0	Hobe series	fine grained sand, 10YR3/1, with many uncoated sand grains	0:E horizon	none
T7-1-40	20-40	0	Hobe series	same as above but 10YR6/1, to 70 cm		none
T7-1-60	40-60	0	Hobe series			non
T7-1-80	60-80	0	Hobe series	70: 10YR4/3	70:Bh	none
T7-1-100	80-100	0	Hobe series	80:loamy fine sand, 10YR2/2; 90:Bh2	90:Bh2	none
T7-1-120	100-120	0	Hobe series			none
none	204	0	Hobe series	sandy to 204+ cm		none
T7-2-20	0-20	15	Terra Ceia Variant inclusion	5YR2.5/1, no sand		10
T7-2-40	20-40	15	Terra Ceia Variant inclusion	5YR2.5/1, no sand		10
T7-3-20	0-20	165	Okeelanta Variant			15
T7-3-40	20-40	165	Okeelanta Variant			15
no sample	180	165	Okeelanta Variant	180:sand layer		15
T7-4-20	0-20	145	Okeelanta	5YR2.5/1		27
T7-4-40	20-40	145	Okeelanta			27
T7-4-60	40-60	145	Okeelanta			27
no sample	130	145	Okeelanta	130:sand layer		

Samples collected May 20, 2004.
Data from “Soils Survey of the Loxahatchee River Floodplains,” by Li et al., University of Florida, Gainesville.

Table D-7. Transect #9 Soils Characteristics and Groundwater Depth.

Sample ID	Depth (cm)	Length, transect (m)	Soil name	Soil description	Horizon (cm)	Water table depth (cm)
T9-1-20	0-20	0-10		Pomello Series		not found
T9-1-40	20-40	0-10		Pomello Series		not found
T9-1-60	40-60	0-10		Pomello Series		not found
T9-1-80	60-80	0-10		Pomello Series		not found
T9-1-100	80-100	0-10		Pomello Series		not found
T9-1-120	100-120	0-10		Pomello Series		not found
T9-1-140	120-140	0-10		Spodic Horizon at 125 cm		not found
T9-2-20	0-20	25-35		Okalanta Muck		46
T9-2-40	20-40	25-35		Okalanta Muck		46
T9-2-60	40-60	25-35		Okalanta Muck		46
T9-2-80	60-80	25-35		Okalanta Muck		46
no sample	155			Mineral layer at 155 cm		46
T9-3-20	0-20	55-65				40
T9-3-40	20-40	55-65				40
T9-3-60	40-60	55-65				40
T9-3-80	60-80	55-65				40
T9-3-100	80-100	55-65		Mineral layer at 90 cm		40
T9-4-20	0-20	175-185				25
T9-4-40	20-40	175-185				25
no sample	168	175-185		Mineral layer at 168 cm		25

Samples collected May 18, 2004.
Data from “Soils Survey of the Loxahatchee River Floodplains,” by Li et al., University of Florida, Gainesville.

Appendix E

1989 Agreement between the South Florida Water Management District and the South Indian River Water Control District

LL060501

AGREEMENT
BY AND BETWEEN
SOUTH FLORIDA WATER MANAGEMENT DISTRICT (SFWMD)
AND
SOUTH INDIAN RIVER WATER CONTROL DISTRICT (SIRWCD)
CONCERNING
THE SIRWCD SURFACE WATER MANAGEMENT SYSTEM
AND
THE ENVIRONMENTAL ENHANCEMENT AND FLOOD PROTECTION OF
THE LOXAHATCHEE RIVER NORTHWEST FORK

IT IS HEREBY AGREED by and between SOUTH FLORIDA WATER MANAGEMENT DISTRICT, hereinafter referred to as "SFWMD", and SOUTH INDIAN RIVER WATER CONTROL DISTRICT, hereinafter referred to as "SIRWCD", as follows:

1. Both parties seek to provide for the Environmental Enhancement and Flood Protection of the Loxahatchee River Northwest Fork and for Beneficial Water Management and Flood Protection for the Area served by the SIRWCD. It is the intent of the participating agencies to operate in a manner consistent with the surface water management regulations of the SFWMD and the restoration objectives outlined in the Loxahatchee River Wild and Scenic River Management Plan as adopted by the Governing Board of the SFWMD and the Governor and Cabinet of the State of Florida.

2. The overall operational objective will be to enhance water quantity and quality of the loxahatchee River Northwest Fork, reduce the frequency of direct discharges to tide water through S-46, improve local groundwater storage, and provide increased flood protection through storm water management. To accomplish this goal, the SFWMD has replaced the older G-92 structure with a larger capacity structure capable of diverting S-46 discharges, and redirecting these flows, up to four hundred cubic feet per second (400 cfs), to the Loxahatchee River Northwest Fork. To the extent feasible, a minimum base flow of fifty cubic feet per second (50 cfs) will be maintained to the Loxahatchee River Northwest Fork throughout the year. However, the restoration goal is to sustain flows above this level whenever possible and when consistent with environmental objectives. The G-92 structure has also been designed to allow flood waters from SIRWCD to backflow to C-18 under certain conditions.

3. In consideration for the above-described benefits to be derived from implementing an improved water management system, SFWMD has agreed to pay for the construction of the low head capacity pump station and water control structures described in paragraph 6. The purpose of the pump station and water control structures is to remove and store excess runoff from the SIRWCD

drainage system, to reduce overdrainage, provide groundwater recharge, and provide for enhancement of water quality and base flows to the Northwest Fork.

4. Operation and maintenance of G-92 will be the responsibility of SFWMD. Gate operation will be remotely operated and under the direct control of SFWMD Operations Staff at the West Palm Beach headquarters. Facilities to manually override the automatic systems will be provided to the SIRWCD for emergency purposes. During emergency conditions, SIRWCD shall seek to notify SFWMD of its intended action before making any operational changes in G-92 in accordance with criteria established in the operating permit. In non-emergency conditions, prior approval from SFWMD is required before any changes in gate status are attempted by SIRWCD staff.

5. Gate adjustments and discharge through G-92 will be governed by the structure headwater and tailwater stages, to be determined by SFWMD, with information supplied to SIRWCD. Equipment will be installed and maintained by SFWMD to remotely monitor these stages from SFWMD headquarters. This stage data will be obtained continuously and made available to SIRWCD. For purposes of river flow augmentation, SFWMD will be allowed to discharge from C-18 of SFWMD to C-14 of SIRWCD through G-92, a quantity of water in cubic feet per second (cfs) equivalent to the maximum discharge capacity of the structure or four hundred

cubic feet per second (400 cfs), whichever is less, and with the provision that the C-14 stage shall not exceed 14.5 feet National Geodetic Vertical Datum (NGVD) during operation. For purposes of flood control SFWMD shall operate S-46 and G-92 so as to give maximum opportunity for flow from C-14 to C-18 when the water in C-14 at G-92 exceeds 15.0 feet NGVD. Flood control operations will continue until the stage recedes to 14.5 feet NGVD in C-14 or to the C-18 stage, whichever occurs first.

6. SFWMD will pay for construction of a pump station with a minimum capacity of 100 cubic feet per second (100 cfs) at the southern perimeter of the SIRWCD Lateral Canal #7. Water pumped from the SIRWCD Canals will be discharged to the Slough Management Area as described in conceptual surface water management permits submitted by SIRWCD (02255-D) and Foundation Land Company (12102-A) and approved by SFWMD Governing Board and any subsequent modifications thereof. Operation of the pump station, when completed, will be in accordance with a management plan mutually acceptable to SFWMD and SIRWCD as reflected in the construction and operation permits therefor. SFWMD agrees that any improvements in the C-18 works, including levee and culvert modifications, will be the responsibility of SFWMD. SFWMD will pay for construction of lateral canal water control structures as permitted in DER Permit Number 501075426. SIRWCD will design, construct, assume ownership, all liability, and costs of operation and maintenance of the pump station and control

structures. The total cost of the pump station and water control structures including engineering design and services during construction shall not exceed $750,000. Disbursement of funds shall be to SIRWCD upon submission of payment requests for completed work approved by the SIRWCD Engineer.

7. SIRWCD shall grant to SFWMD a perpetual Flowage Easement over C-14 from G-92, north to the limits of SIRWCD. SFWMD shall not restrict, reduce or otherwise limit any rights of SIRWCD from discharging surface waters into C-14 except as set forth in the construction and operation permit referenced in paragraph 6.

8. SFWMD agrees to provide SIRWCD access to the SFWMD C-18 right-of-way along both East and West sides of the Canal from the newly constructed C-14 Bridge located at the intersection of 157 Street and C-18, North to the Reese Bridge crossing C-18. SIRWCD assumes all liability for and agrees to maintain levee and berm surfaces for those portions of the SFWMD C-18 right-of-way used by SIRWCD. SIRWCD further agrees to assume responsibility for security of the C-18 right-of-way which it uses, including maintenance of all SFWMD security gates used by SIRWCD personnel to gain entry to the C-18 right-of-way. SIRWCD will supply all necessary locks and ensure that duplicates of all lock keys are transmitted to the SFWMD including duplicates for any lock

replacements. SFWMD will have a continued, non-restricted right of access throughout the entire C-18 right-of-way, including those portions utilized by SIRWCD.

9. SFWMD agrees to transfer ownership of the C-14 Bridge and related property to SIRWCD. SIRWCD agrees to assume ownership, liability, security and maintenance of the C-14 Bridge and hold SFWMD harmless in all respects.

10. SFWMD agrees to provide SIRWCD the exclusive use of the Reese Bridge, until such time that the Donald Ross Road Extension is completed across C-18. Upon completion of the Donald Ross Road Extension, use of the Reese Bridge by SIRWCD will terminate and the Bridge may be removed at the discretion of the SFWMD. SIRWCD agrees to assume all liability for and maintenance of the Reese Bridge while it is used exclusively by SIRWCD and hold SFWMD harmless in all respects.

11. The use of the District facilities provided for herein shall be deemed to constitute a permit for the utilization of works or lands of the District pursuant to Chapter 40E-6, Florida Administrative Code, and shall be subject to the provisions thereof, except when in specific conflict with the terms of this agreement, in which event the terms of the agreement shall prevail.

12. The obligations of SFWMD and SIRWCD as set forth in this agreement are contingent upon:

A) SFWMD and SIRWCD reaching an agreement with the landowner of the "slough" referred to in paragraph 6 for receiving discharge from the pump station,

B) SIRWCD securing or determining that it has the necessary authority to own, operate and maintain the pump station and water control structures referred to in paragraph 6.

C) Issuance of the construction and operation permit referred to in paragraph 6.

Prior to satisfying the above conditions both SFWMD and SIRWCD agree to temporarily operate G-92 as set forth in paragraph 5.

12. Modifications or deviations from the basic intent of the above agreements must be approved by both parties. Requests for modifications or alterations must be submitted in writing.

IN WITNESS WHEREOF, the parties hereto have caused this Agreement to be executed by their officers thereunto duly authorized, and their Corporate Seals to be affixed, and attested to by their Secretaries, on this the day and year below written.

SOUTH FLORIDA WATER MANAGEMENT DISTRICT

By: ______________________
Chairman

DATE: 7/13/89

ATTEST:

____
Its: Secretary

CORPORATE SEAL

SOUTH INDIAN RIVER WATER CONTROL DISTRICT

By: ______________________
President

DATE: 7-11-89

ATTEST:

____
Its: Secretary

CORPORATE SEAL

Page 8

Appendix F

1982 Consent Decree

SJN/ep
C-18

IN THE CIRCUIT COURT OF THE FIFTEENTH JUDICIAL CIRCUIT OF FLORIDA, IN AND FOR PALM BEACH COUNTY

CASE NO. 79-1910 CA (L) 01 C

FLORIDA WILDLIFE FEDERATION,
Non-Profit Florida Corporation,

Plaintiff,

vs

THE FLORIDA DEPARTMENT OF ENVIRONMENTAL REGULATION and THE SOUTH FLORIDA WATER MANAGEMENT DISTRICT,

Defendants.

FINAL ORDER

This Court, having considered the "Stipulation for Consent Decree" signed by all of the parties to this cause, and being otherwise fully advised in the premises herein finds and it is thereupon

ORDERED AND ADJUDGED as follows:

1. The aforesaid "Stipulation for Consent Decree", attached hereto, is hereby adopted as the Order of this Court, said Stipulation constituting a final disposition of all matters at issue in this case.

2. This Court reserves jurisdiction to ensure compliance with the terms of this Order.

DONE and so ORDERED in Chambers at the Palm Beach County Courthouse, West Palm Beach, Florida, this 19 day of July, 1982.

TIMOTHY P. POULTON
Judge of Circuit Court

Copies furnished to: Thomas J. Schwartz, Esquire
Thomas E. Kingcade, Esquire
Alfred J. Malefatto, Esquire

SJN/ph
C-18

IN THE CIRCUIT COURT OF THE FIFTEENTH JUDICIAL CIRCUIT OF FLORIDA, IN AND FOR PALM BEACH COUNTY

CASE NO. 79-1910 CA (L) 01 C

FLORIDA WILDLIFE FEDERATION,
Non-Profit Florida Corporation,

Plaintiff,

vs

THE FLORIDA DEPARTMENT OF ENVIRONMENTAL REGULATION and THE SOUTH FLORIDA WATER MANAGEMENT DISTRICT,

Defendants.

STIPULATION FOR CONSENT DECREE

The parties, FLORIDA WILDLIFE FEDERATION; STATE OF FLORIDA DEPARTMENT OF ENVIRONMENAL REGULATION (hereinafter "the DER") and the SOUTH FLORIDA WATER MANAGEMENT DISTRICT (hereinafter "the District"), by and through the undersigned attorneys, hereby stipulate to the entry of a Final Order in the above-styled case in accordance with the following terms and conditions:

1. Subject to the approval of the United States Army Corps of Engineers, the District shall maintain an operating schedule for the S-46 gated spillway, so that the "dry season" operating schedule is maintained on a year round basis. This schedule provides for automatic opening of the structure when water levels in the C-18 canal reach a level of 15 feet msl. The structure becomes stationary at 14.5 feet msl and closes at 14 feet msl. In the event of an impending hurricane, tropical storm or other significant rainfall event, the District may in its discretion make releases from the S-46 gated spillway in anticipation of any such event, which may lower the water elevation in the C-18 Canal below the agreed operating level.

2. The District shall schedule the program for control of aquatic weeds within the C-18 canal right of way so as to minimize the use of herbicides, subject to cost considerations regarding alternative methods of aquatic weed control. Those herbicides as are used by the District shall be approved by the Environmental Protection Agency and permitted by the Florida Department of Natural Resources.

3. The District shall ascertain the ownership of the "Lainhart Dam" and shall, as soon as possible utilize District forces, exercise all due diligence to arrange for the restoration of the Dam to the structural condition that would control discharge conditions

as described in the District's C-18 Culvert Operation Manual of September 1974. This shall be for the purpose of maintaining higher groundwater stages in the area tributary to the Northwest Fork of the Loxahatchee River and to facilitate the transfer of water from the "diversion culvert" presently existing at the junction of the District's C-18 canal and the South Indian River Drainage District's C-14 canal to the Northwest Fork of the Loxahatchee River.

4. Subject to the presence of available water supplies, the District shall in cooperation with ENCON, make releases through the aforesaid "diversion culvert" which are adequate to maintain a mimimum flow of approximately 50 cfs in the Northwest Fork of the Loxahatchee River. The determination as to availability of water supplies shall be within the sound discretion of the District, based upon rainfall conditions.

5. The District shall use existing inflow culverts, modified as necessary, to maintain water levels within the area commonly known as the "Loxahatchee Slough" at such levels as are adequate to maintain the existing natural wetland ecosystem in the subject area. The parties recognize that the District shall have reasonable discretion to vary the period during which water levels are maintained at maximum levels, depending upon rainfall conditions, flood control considerations and environmental factors; and that in order to maintain natural conditions and vegetation in the subject area, it will be necessary for the District to lower water levels during the "dry season", with the precise time period thereof being within the reasonable discretion of the District.

6. The District's Governing Board, shall recommend to the United States Army Corps of Engineers that the existing federally authorized project be modified to return, to the maximum extent possible, to the natural regimen that existed in regard to the tributaries to the Loxahatchee River prior to the construction of the C-18 canal and the S-46 gated spillway. This involves diverting surface water flows to the "Northwest Fork" of said river to its maximum carrying capacity prior to making surface water discharges to the "Southwest Fork" of the river. The District shall recommend that the aforesaid objective be accomplished through the following modifications to the federal project:

a) Developing the capability to divert a greater flow of surface water runoff from C-18 to the Northwest Fork of the Loxahatchee River.

b) Maintenance of a water retention area for the purpose of accommodating surface water runoff from those lands within the Loxahatchee Slough area and areas tributary to the Northwest Fork of the Loxahatchee River.

7. The parties recognize that the aforesaid project modifications are contingent upon approval by the United States Army Corps of Engineers, and appropriate federal, state and local regulatory agencies. The District agrees to exercise all due diligence to acquire the property rights and obtain all necessary permits.

8. The parties also recognize that the District shall continue to make discharges through the S-46 gated spillway for flood control purposes before, during and after certain rainfall events, but that in the event the federal project is modified to permit discharges to the Northwest Fork of the Loxahatchee River, the District shall utilize the Northwest Fork as its primary discharge facility and shall operate the water control system so as to maximize the use of said Northwest Fork prior to making discharges through the Southwest Fork, with the exception that discharges may still be made at the Southwest Fork prior to exceeding the maximum carrying capacity of the Northwest Fork in anticipation of extreme rainfall events.

9. Each party shall bear its own respective costs and attorneys fees for all proceedings in this case.

Thomas E. Kingcade

THOMAS E. KINGCADE, Attorney for FLORIDA WILDLIFE FEDERATION, Plaintiff
Post Office Box 2755
Palm Beach, Florida 33480
(305) 655-3751

Thomas J. Schwartz

THOMAS J. SCHWARTZ, Attorney for SOUTH FLORIDA WATER MANAGEMENT DISTRICT, Defendant
Post Office Box V
West Palm Beach, Florida 33402-4238
(305) 686-8800

Alfred J. Malefatto

ALFRED J. MALEFATTO, Attorney for FLORIDA DEPARTMENT OF ENVIRONMENTAL REGULATION, Defendant
2600 Blair Stone Road
Tallahassee, Florida 32301
(904) 488-9730

3

Appendix G

Water Quality, Tide and Salinity Monitoring Information

Table G-1. Loxahatchee River District (LRD) RiverKeeper Water Quality Parameters and Units.

RiverKeeper Water Quality Parameters	Units
Date	
Time	
Depth	Meters
Alkalinity, Bicarbonate as CaCO3	mg/l
BOD, Biochemical oxygen demand	mg/l
Chlorophyll a, uncorrected for pheophytin	mg/l
Depth, Secchi disk depth	m
Dissolved oxygen (DO)	mg/l
Dissolved oxygen saturation	%
Light %	at 1Meter
Light %	at 2Meters
Nitrogen, Ammonia	mg/l
Nitrogen, Kjeldahl	mg/l
Nitrogen, Nitrite (NO2) + Nitrate (NO3)	mg/l
Nitrogen, Organic	mg/l
Nitrogen, Total	mg/l
pH	None
Phosphorus	mg/l
Phosphorus, ortho	mg/l
Salinity	ppt
Secchi	Meters
Specific conductance	umho/cm
Temperature, water	deg C
Tide	Stage
Total Organic Carbon	mg/L
Total Coliform	#/100ml
Total Fecal Coliform	#/100ml
Total Suspended Solids (TSS)	mg/l
True Color	PCU
Turbidity	NTU

Table G-2. Loxahatchee River District (LRD) RiverKeeper Station ID and Locations.

RiverKeeper Stations	Assigned Nos.	NW Fork River Miles
Jupiter Inlet	10	0
ICW - S.R. 707	20	
ICW - M.M. 43	25	
ICW - S.R. 706	30	
Marine SC	32	
ICW – Donald Ross Rd.	35	
River RR Track	40	
Pennock Point	42	2.44
NF - Tequesta Dr.	51	
NF - Countyline Rd.	55	
NF - JD State Park	57	
NF - Power Line	58	
NF - Bridge Rd	59	
NWF - Bay	60	1.48
NWF – Island Way Rd.	62	
NWF - Osprey Nest	63	
NWF - JD Park Beach	64	
NWF - Kitching Cr.	65	8.13
NWF - Hobe Grove	66	9.07
NWF - Trapper's	67	10.50
NWF - I - 95	68	12.76
NWF - S.R. 706	69	14.93
SWF - Jones Cr.	71	
SWF - Lox. River Rd.	72	
SWF - Sim's Creek	73	
C18 - S.R. 706	81	
B- Inflow from C-18	83	
H- Outflow to C-14	84	
G- Wood Bridge Outflow	85	
C14 - D. stream of G92	92	
Canal -1- Jupiter Farms	95	
Cypress - NWF	100	
Jenkins Canal	101	
North Wetland	102	
South Wetland	103	
Hobe Grove Canal	104	
Cypress -Grove Canal	105	
Kitching Creek	106	
River's Edge Slough	107	
Kitching Creek North	109	
Bridge Road Sod Farm	110	
Kitching Ck. @ 138 th St.	111	
Kitching Ck. @ Bridge Rd.	112	

USGS TIDE AND SALINITY MONITORING STATIONS

Table G-3. USGS Long-term Tide and Salinity Monitoring Sites.

Coordinates[a]		Site		Description
X (feet)	Y (feet)	Station ID	River Mile	
955325	951200	CG	0.7	USGS Coast Guard
949538	950648	PD	1.77	USGS Pompano Drive
935708	965258	BD	5.92	USGS Boy Scout Dock
931399	966948	KC	8.13	USGS Kitching Creek
929733	964696	RM9	9.12	USGS River Mile 9.1

[a] State Plane Florida East NAD83.

Table G-4. Parameters of USGS Long-term Tide and Salinity Monitoring Sites.

Station ID	River Mile	Period of Record	Parameters Monitored
CG	0.7	Since Nov 2002	Water surface elevation, temperature and salinity at two depths.
PD	1.77	Since Nov 2002	Water surface elevation, temperature and salinity.
BD	5.92	Since Nov 2002	Water surface elevation, temperature and salinity at two depths.
KC	8.13	Since Nov 2002	Water surface elevation, temperature and salinity.
RM9	9.12	Since Oct 2003	Water surface elevation, temperature and salinity at two depths.

LOXAHATCHEE RIVER DISTRICT (LRD) TIDE AND SALINITY MONITORING STATIONS

Table G-5. Loxahatchee River District (LRD) Long-term Tide and Salinity DataSonde Monitoring Sites.

Coordinates[a]		Site		Description
X (feet)	Y (feet)	Station ID	River Mile	
		DSNB	1.48	LRD North Bay
		DSPP	2.44	LRD Pennock Point
		DSKC	8.12	LRD Kitching Creek
		DS66	9.5	LRD RM 9.5
		DS69	14.93	LRD RM 14.93

[a] State Plane Florida East NAD83.

Table G-6. Parameters of Loxahatchee River District (LRD) Long-term Tide and Salinity DataSonde Monitoring Sites.

Station ID	River Mile	Period of Record	Parameters Monitored
DSNB	1.48	Since May 2004	Water surface elevation, temperature at two depths, salinity at two depths, conductivity.
DSPP	2.44	Since May 2004	Water surface elevation, temperature at two depths, salinity at two depths, conductivity.
DSKC	8.12	Since Jan 2000	Water surface elevation, temperature at two depths, salinity at two depths, dissolved oxygen at two depths and pH.
DS66	9.5	May 1, 2004 – August 12, 2004	Water surface elevation, temperature, salinity, dissolved oxygen and pH.
DS69	14.93	Since Jan 2000	Water surface elevation, temperature, salinity, dissolved oxygen and pH.

Appendix H

Fish Larvae Studies

Introduction

This fish larvae study was undertaken during the dry season (May and June 2004) to determine the influence of the low salinity zone (LSZ) in the Northwest Fork has on larvae recruitment and abundance as well as species composition (Shenker et al. 1983; Houde 1994; Blaber 2000; Dege and Brown 2004). Larvae were sampled weekly from four locations from the Boy Scout Camp Dock to the Trapper Nelson's historical site. The results of this study will be used to determine the flow at which the influx of larvae utilizing the Loxahatchee LSZ may be stressed.

Methods

Four regions between River Miles 6 and 10 were chosen for the initial collections in this portion of the Loxahatchee River (**Figure H-1**). Each region centered on/around RM 7, RM 8, RM 9, and RM 10 with a single replicate tandem plankton tow from 20m to50m of the previous tow creating eight paired stations: Stations #1 and #2 (RM 10), Stations #3 and #4 (RM 9), Stations #5 and #6 (RM 8) and Stations #7 and #8 (RM 7). During late June (25th) and early July (6th) Stations 1 and 2 were abandoned due to extremely low water levels.

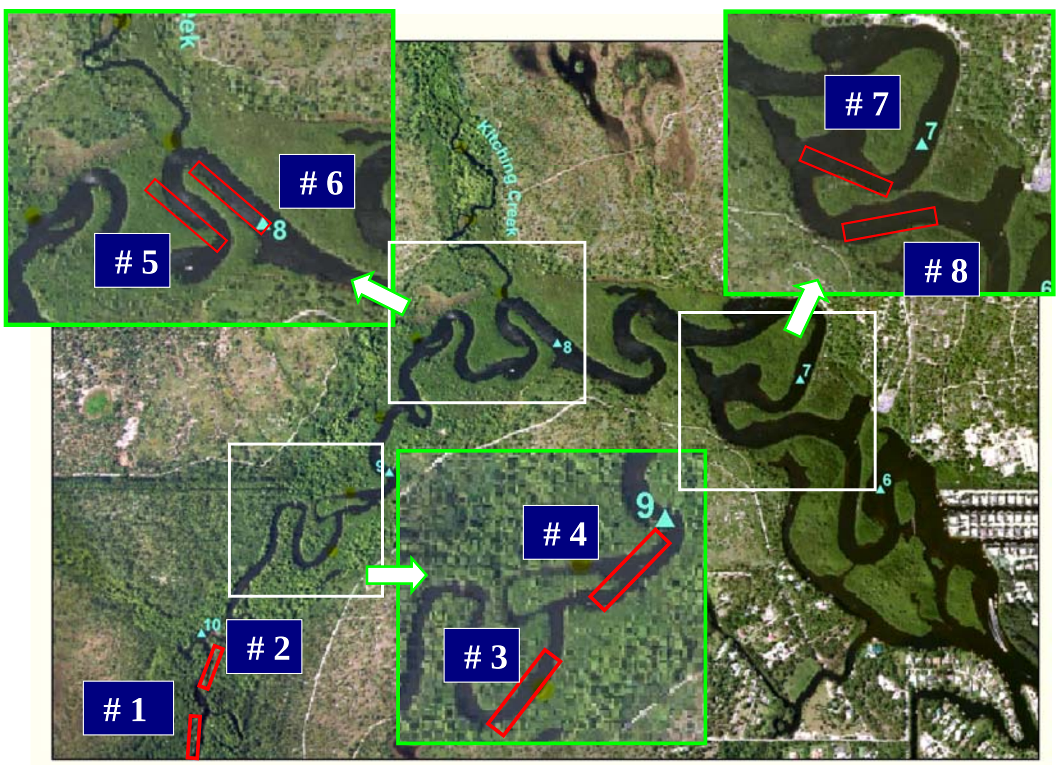


Figure H-1. Location of Zooplankton Transects. Blue Numbers Indicate River Mile, White Numbers on Blue are Station Numbers. East, Downstream is to the Right.

The mid to late dry season was chosen for study to determine the extent of saline intrusion into the Loxahatchee River relative to zooplankton, particularly fish larvae. Previous work in tropical American estuaries had indicated that major migrations of fish larvae occur from the ocean or estuary into riverine ecosystems during the dry season each spring, just before the wet season begins. Initial experimental collections were made on 17 May 2004 to determine practical limitations in sampling frequency, location and gear behavior. The first routine samples were made during a flooding tide on 17 June. All samples were taken between 1912 and 0030 hours 17 June through 6 July. Nocturnal plankton tows were made using a 0.5-m diameter, 500 micron mesh plankton net pulled 50 m behind a the boat. A 1.0 to 2.0 minute tow was made at each site at standard boat rpm rate of 1,500 rpms, which translated to 0.832 - 1.13 m/sec, or 49 to 136 m per tow. Samples were fixed in 10% buffered formalin for 1 week then rinsed in freshwater and placed in 35% isopropyl alcohol for preservation. All specimens were sorted and identified using a Wild M5 stereo-microscope and placed in species specific containers for permanent storage in 35% isopropyl alcohol.

Water quality information was collected during sampling, however, the most robust data were obtained from continuously recording USGS water quality monitoring sites located from 0 m to 200 m of the tow site. The primary data of interest were salinity and water level information as these parameters were most likely to reveal salinity frontal boundaries and water flow/level conditions, factors which have great influence on biota distribution in the water column and river channel.

Temporal and spatial variations in fish larval and planktonic invertebrate communities were examined statistically using non-parametric statistics due to a variety of data limitations, most notably temporal and sample intensity constraints. Non-parametric statistics were used to determine spatial, temporal and physical parameter relationships with the zooplanktonic community. The PRIMER (Plymouth Routines In Multivariate Ecological Research) statistical program was used for data analyses.

Results

2004 ZOOPLANKTON COLLECTIONS

***Total Zooplankton Community Definition**:* Nineteen 1-2 minute plankton tows captured 124,436 zooplankters on June 17, 25 and July 6, 2004. These samples were sorted and identified with emphasis on larval fish, however, every invertebrate was kept for documentation. Larval fish were often identifiable to species except for eleotrids and gobies. There are at least thirteen larval gobioid fishes (Gobiidae and Eleotridae) that occur within the Loxahatchee River. The larval stages of a number of these have not been described, most notably the tropical *Ctenogobius* species (*C. pseudofasciatus* and *C. fasciatus*), *Awaous banana*, *Gobiomorus dormitor* and *Gobioides brousonettii*. Complete developmental series of *Gobiosoma bosc* were captured and the eleotrid, *Dormitator maculatus* was well represented. However, for these analyses familial and superfamily level classifications were most practical. The only larval pipefish captured were opossum pipefish, *Microphis brachyurus lineatus*. This is the first time larval opossum pipefish were captured as they migrated seaward from their release in freshwater tributaries.

A total of 27 different taxonomic groups were separated for this analysis. Crustaceans dominated the samples accounting for 80% to 96% of the number of individuals captured **Figure H-2**. Larval fish abundance increased from >1% of the catch to 4%. No eggs were collected on June 17, but 1,092 of at least three types were collected at Stations 7 and 8 on June 25; on July 6, 20 eggs were collected at Station 3 and 27 eggs were collected at Station 8. This indicated spawning activity in late June and upstream and downstream in early July. Circular eggs with oil droplets were attributed to fish spawning activity.

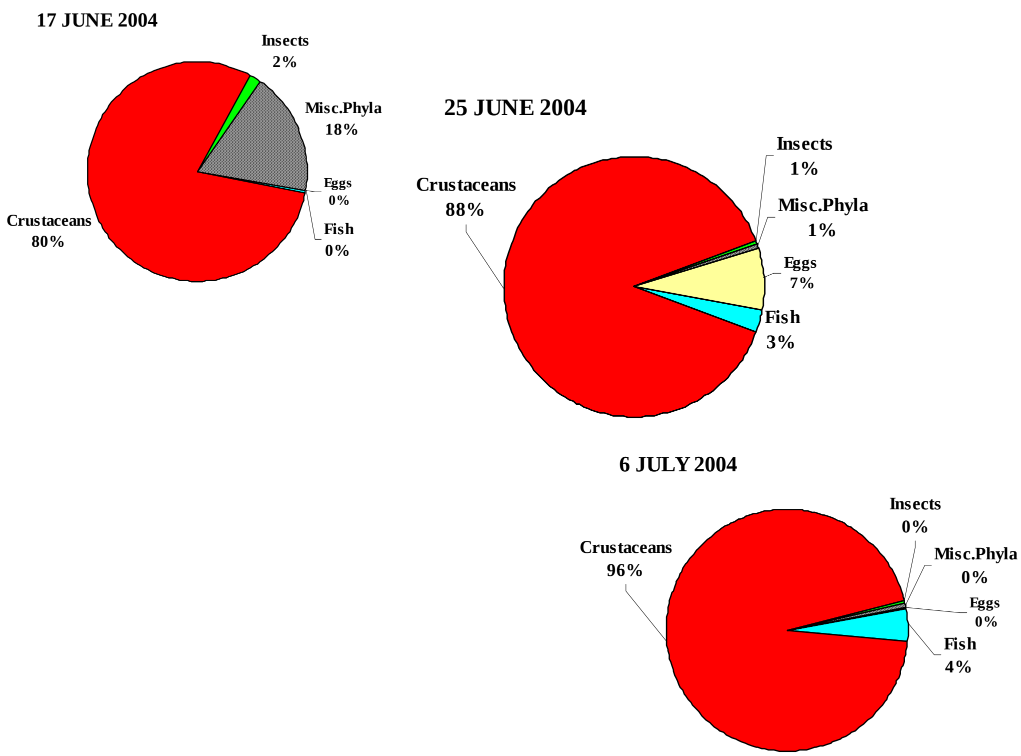


Figure H-2. Composition of Entire Zooplankton Collection Based on Number of Individuals Captured.

The “meroplankton,” which are temporary zooplankton consisting primarily of the larval stages of various non-planktonic aquatic or aerial/terrestrial organisms, were separated from the “holoplankton,” which are those planktonic groups that spend their entire life history in a planktonic environment. Several mysid morphologies were observed and placed in the holoplankton category.

The holoplankton consisted primarily of mysids (at least two species), cumaceans and copepods (**Figure H-3**). Relative numbers of mysids increased significantly, an order of magnitude from 17 June, 45% (111 individuals), to 25 June, 91% (1,899 individuals), then decreased to 77% (1,594 individuals) by 6 July (**Figure H-3**). Mysids were consistently most abundant at Station 6, at the mouth of Kitching Creek. Cumaceans declined in relative abundance, contribution to the entire sample, but total numbers remained about the same or increased as well as an increase in the number of sites they were captured, one to four of six stations from 17 June to 6 July. Cumacean populations were most abundant at the higher salinity locations, Stations 5, 6, 7, and 8. Copepods were not most effectively captured with a 505 micron mesh plankton net, so accurate numbers were not obtained. However, nearly all copepods were captured at the highest salinities at Stations 7 and 8, increasing numbers from 17 June, 69 individuals to 322 individuals on 6 July.

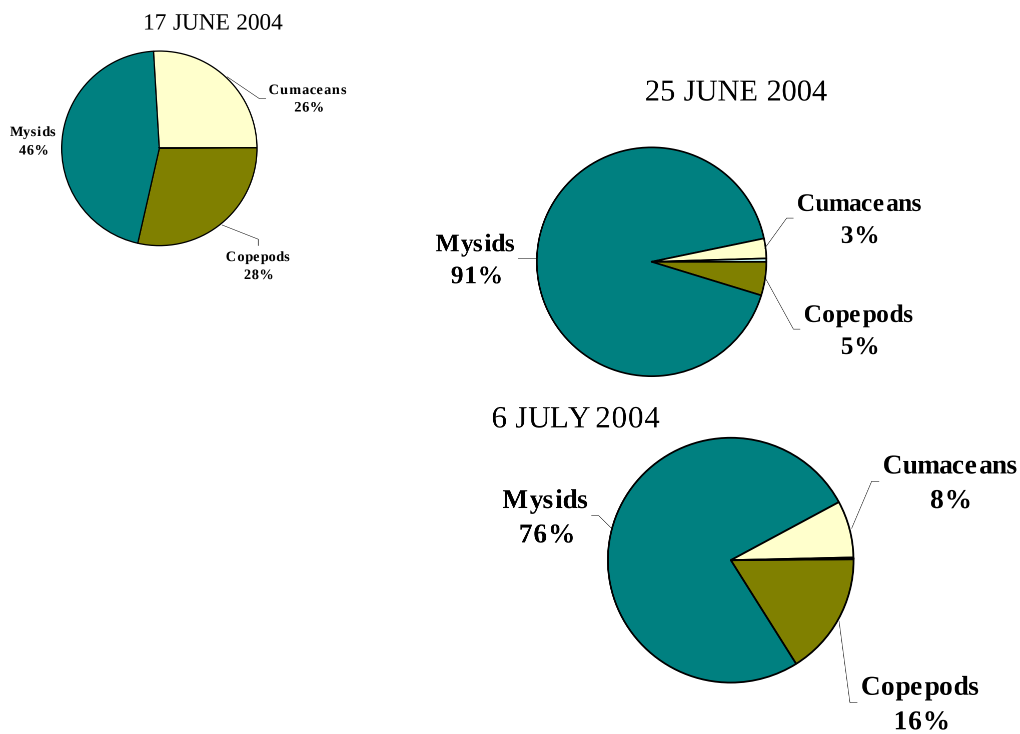


Figure H-3. Crustacean Holoplankton Contribution Based on Densities (number/m^3).

Temporal analysis of the meroplankton was divided between crustacean and teleostean taxa. Crustacean meroplankton consisted of brachyuran crab larvae, zoea, megalopa and palaemonid shrimp, as well as cypriid, barnacle parts (**Figure H-4**). Also included were peracardean crustaceans, amphipods (three species) and isopods (two species). Judging from the number of amphipod tubes and benthic isopods captured it is possible that these latter taxa were brought up from the bottom by turbulence from the boat passage or with net contact with the bottom, however, the majority of individuals were captured at the deeper higher salinity stations downstream, Stations 7 and 8, where it was least likely that the net or boat motor turbulence came in contact with the bottom. Amphipods contributed 7% to 26% of the total crustacean meroplankton catch, increasing in numbers captured from 668 17 June to 2,911 on 6 July. Zoea larvae contributed the largest relative number of individuals to the meroplankton, 49% (1,264 individuals) 17 June increasing to 84% of the catch (9,307 individuals) on 25 June, then declining to 64% (7,337 individuals) by 6 July. The majority of zoea larvae were captured at Station 5 on 17 June, but at Station 6, 25 June and 6 July surrounding the mouth of Kitching Creek. The majority of megalopa larvae were captured at Stations 5 and 6 around the mouth of Kitching Creek, particularly at Station 6; 25 June and 6 July.

When comparing overall abundance of meroplankton versus holoplankton it is obvious that the temporary increase in larval forms of crustaceans and teleosts makes the greatest overall contribution to the zooplankton of the Loxahatchee River using a 505 micron mesh net.

Fish contributed a relatively small percentage of the meroplankton and total zooplankton, 0.01% to 4% in our collections (**Figure H-3**). Station and monthly trends in ichthyoplankton abundance follows that of the meroplankton with increases in overall fish abundance from

10 individuals captured on 17 June to 423 and 461 on 25 June and 6 July. The majority of fish larvae captured on 25 June and 6 July were captured at Station 6, which is just downstream of Kitching Creek. The most numerous taxa were gobioid fishes (gobiidae and eleotridae). The most abundant identifiable species was the naked goby, *Gobiosoma bosc*, a benthic species that typically associates with benthic structures such as oyster reefs. At least five other species of gobies contributed to our gobioid larval collections, but these species have not been definitively identified. There are fifteen additional gobies known to occur in the Loxahatchee River. These gobies are the freshwater tolerant species. Gobies by far outnumber all other ichthyoplankton families in biomass, numbers and species. They represent the richest and most productive fish larval component in the Loxahatchee River ecosystem. The Loxahatchee, St. Lucie and St. Sebastian Rivers contain the richest gobioid fish fauna within the continental United States (Hastings 1979; Gilmore in prep.).

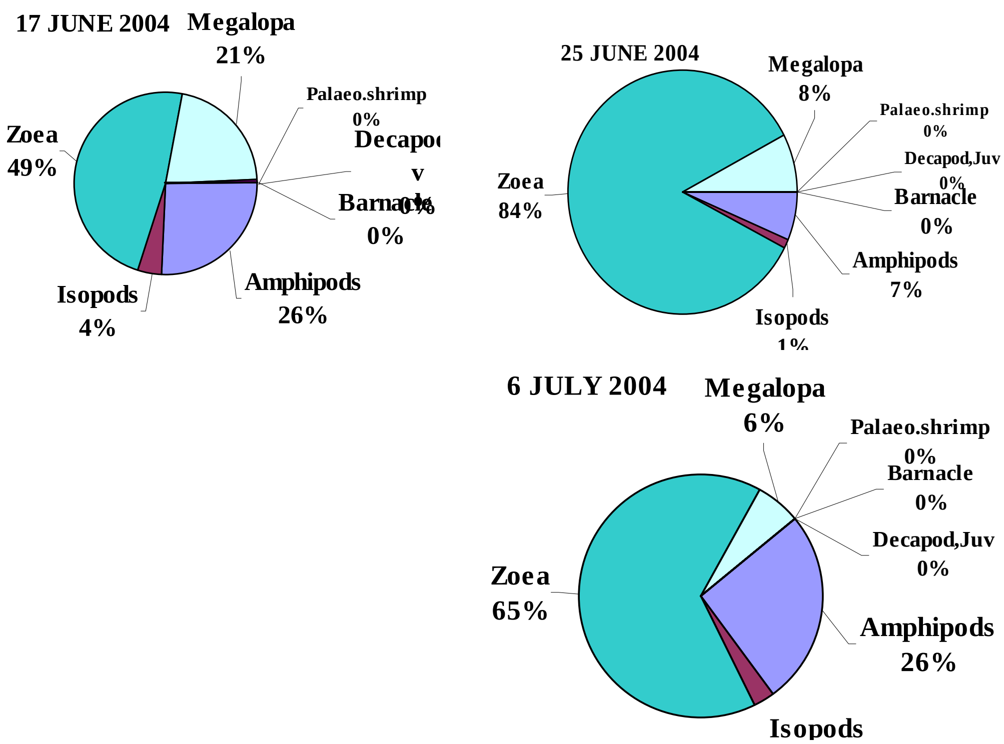


Figure H-4. Crustacean Meroplankton Composition Based on Densities.

The next most abundant fish larvae were the anchovies (engraulidae) which also substantially increased in abundance from 17 June (1 individual) to 6 July (86 individuals), over 75% of these being taken at Station 6, near the mouth of Kitching Creek. *Anchoa mitchilli* was the only species for which a definitive identification was made. Other *Anchoa* species that have been recorded from the Loxahatchee River and adjacent estuary are *A. hepsetus*, *A. cubana*, and *A. lyolepis*.

Syngnathid larvae were also consistently captured each month increasing from 1 to 7 between 17 and 25 June, declining to 2 on 6 July. All syngnathid larvae were identified as the tropical opossum pipefish, *Microphis brachyurus lineatus*, which is the only catadromous fish species in the Loxahatchee River besides the American eel, *Anguilla rostrata* (not collected). Opossum pipefish juvenile metamorphose to adults in freshwater and spawn in freshwater. The larvae drift downstream to the ocean where they develop for an undetermined period before returning to freshwater to mature and mate. They were first described by Gilmore (1977a,b).

Silversides, atherinidae, were fourth in relative abundance. Four atherinid species occur in the Loxahatchee River and adjacent estuary, *Membras martinica, Menidia beryllina, M. peninsulae* and *Labidesthes sicculus*.

Other notable fish larvae captured include larval tarpon, *Megalops atlantica*, (megalopidae) captured upstream at Station 3 on 6 July and mojarra larvae (gerreidae) captured downstream at Station 7 on 17 June. Though there are at least eleven gerreid species occurring in the Loxahatchee River and adjacent estuary, only four routinely enter freshwater, *Diapterus auratus, Eugerres plumieri, Eucinostomus harengulus* and *E. gula*. Larvae of these species cannot be identified as no descriptions have been published. A larval soleid, *Trinectes maculatus* was taken at Station 6, 25 June.

Notably absent from the Loxahatchee River collections were the larvae of the common snook, *Centropomus undecimalis*. Many larval snook were captured in a plankton tow made in the Jupiter Inlet on 2 July, 2004 where spawning adult snook were noted. However, since our riverine collections were made when local snook populations were spawning, it appears that snook larvae do not enter the Loxahatchee River. However, seine collections made during June and July in the Loxahatchee River not only captured small juvenile stages of the common snook, but also a new record to the continental United States, the smallscale fat snook, *Centropomus mexicanus*.

Also notably absent from these ichthyoplankton collections were any primary freshwater fish species, cyprinids, catastomids or centrarchids. They were totally absent even at the low salinity (<1.0 ppt) stations taken in mid June. They all are known to spawn at this time of year in warm temperate and temperate rivers further north and on Florida's Gulf coast. It appears the Loxahatchee river ichthyofauna is numerically dominated by fish species with marine affinities. Most are diadromus species and tropical.

HISTORICAL 1986-1988 ZOOPLANKTON COLLECTIONS

Zooplankton collections were made within the Loxahatchee River and Estuary from January 1986 to January 1988 by Robert Chamberlain of SFWMD. Monthly zooplankton samples were taken with 5 minute standard tows of a 0.5 m, 505 micron mesh net set from a boom off the side of a boat. These samples were all taken at night on a flooding tide. The two stations whose data were used to compare with the 2004 data were located below Loxahatchee RM 8. Station 28 was located at the same general location as Stations 7 (RM 7.0) and 8 (RM 6.8) taken in 2004. Station 25 was located at RM 5.3. All fish larvae captured during 1986-1988 were identified to species whenever possible. However, these data were used in this study at the family level only. One of the major reasons for this is that the majority of larval gobioid fishes which dominate the Loxahatchee River ichthyoplankton, have not been described as larvae. The potential for a variety of tropical species to occur in the collections is great.

The 1986-1988 study allowed a qualitative and quantitative comparison to be made with 2004 zooplankton collections. From this comparison the Loxahatchee River ichthyoplankton community is defined.

The only location that completely overlapped between the 2004 and the 1986-1988 studies was our Stations 7 and 8 with Chamberlain's Station 28. These sites were identical. For this reason all the monthly collections at Station 28 were used for most of the quantitative analyses in this study. The most complete monthly collection year was 1987. The relative composition of the various fish families to the collections at Station 28 are presented in **Figures H-5 and H-6.** It is obvious that the same families dominated in the same order of numerical abundance in 1987 as it did in our limited collections in 2004: gobioids first (30% - 93% of the April to July 86-87 fish fauna), engraulids second (5%-69%), syngnathids third (0.4%-52%). These three families were the only ones to have 100% occurrence in zooplankton samples in 2004 and April to July in 1986-1987.

Atherinids were common (0 - 5%) in the 25 June 1986 samples as they were in the 25 June 2004 samples (1%). However, clupeids (0-5%) and sciaenids (0-2%) were more abundant in the historical collections on a year round basis. This is undoubtedly due to their spawning activity in fall, winter and spring, periods we missed in our collections.

Chamberlain's Station 25 was examined, as it would give us some indication of potential change in zooplankton densities with salinity. Ichthyoplankton concentrations and species composition was considerably lower at Station 25 when compared to Station 28. This difference is a major factor under examination in the next section, where physical attributes of the water column are examined relative to fish larval abundance.

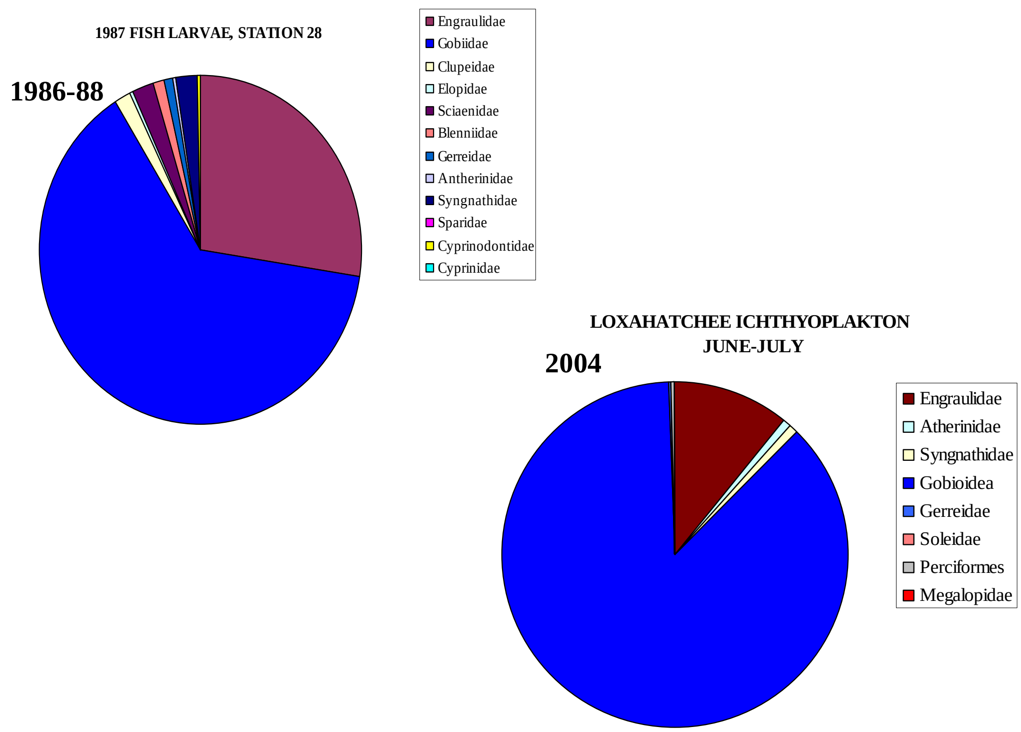


Figure H-5. Ichthyoplankton Composition: All Collections Combined for 1986-1988 and 2004.

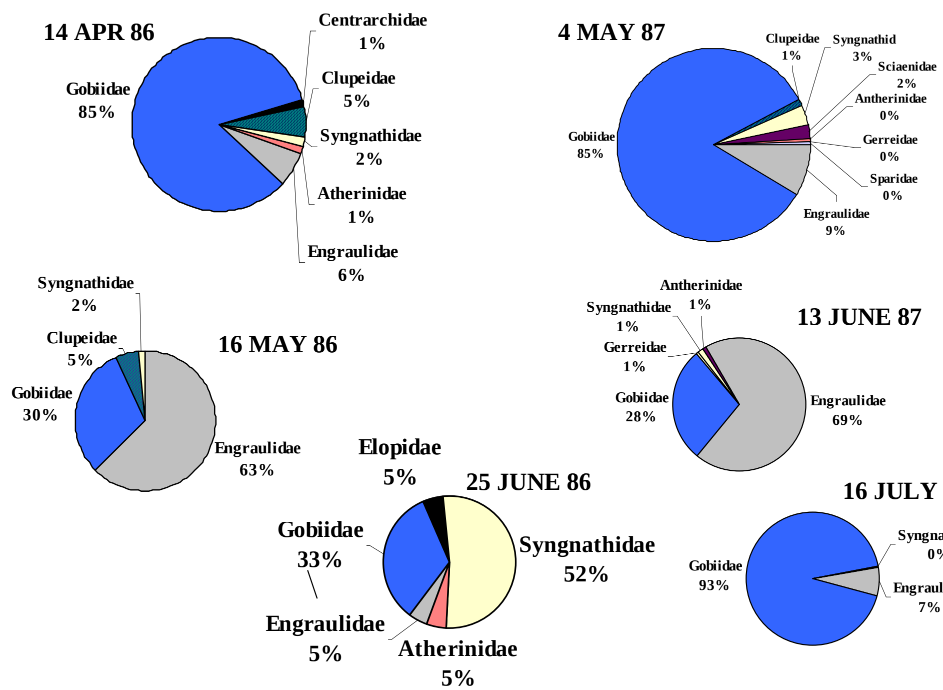


Figure H-6. 1986-1988 Data Showing Seasonal Change in Relative Abundance of Ichthyoplankton During the Spring-Early Summer, Dry-Wet Season Transition.

ICHTHYOPLANKTON DYNAMICS: DIFFERENTIAL INFLUENCE OF WATER LEVEL AND SALINITY

Ichthyofaunal Spatial-Temporal Distribution: Differential Effect of Water Level, Location and Salinity: The major concern in this work was the influence of fresh water versus salt water on ichthyoplankton distribution. Flow rates and turbidity were significant factors. There are several physical parameters for which we had data to compare with our biological collections in the Loxahatchee River. These included dissolved oxygen, various nutrients, water turbidity, flow rates**,** water level, temperature, tides, lunar phase, pH and salinity. Dissolved oxygen remained relatively high through both 1986-1988 and 2004 collection periods with only a couple of instances of significantly low values. Temperature was more of a seasonal factor and not as much a factor at this latitude as water level and salinity. Since obvious water level effects were observed in this very shallow stream, even to the point of not allowing 0.5 m plankton tows to be made upstream of River Mile 9, this parameter had to be examined.

The three primary parameters to be analyzed for this report are water level, station location and salinity. Once water level factors are understood then salinity effects can be clearly defined. Although salinity was chosen as a primary parameter, there are other factors associated with salinity and freshwater flows can influence these data. Turbidity, nutrient levels, phytoplankton productivity and species composition can all show direct relationships to salinity levels. Thus salinity can act as a potential indicator of these other factors. Detailed physical parameter data were taken continuously within minutes at the USGS gauging stations; only the mean values were used.

2004 Water Level Effects: Figure H-7 plots the water level variation during the day of zooplankton collections 17, 25 June, and 6 July 2004. The blue shaded box designates the period of actual sample collection, 1900 – 2400 hrs. Collections were made on an incoming flood tide on 17 June with a mean water level of 1.94 m during the sampling period. Collections made 25 June and 6 July were made on an ebbing tide with maximum water levels of 0.3 m on the 25th, possibly less on 6 July. This presented a significant difference in water levels between the 17 June and the later collections which could potentially influence the zooplankton collections.

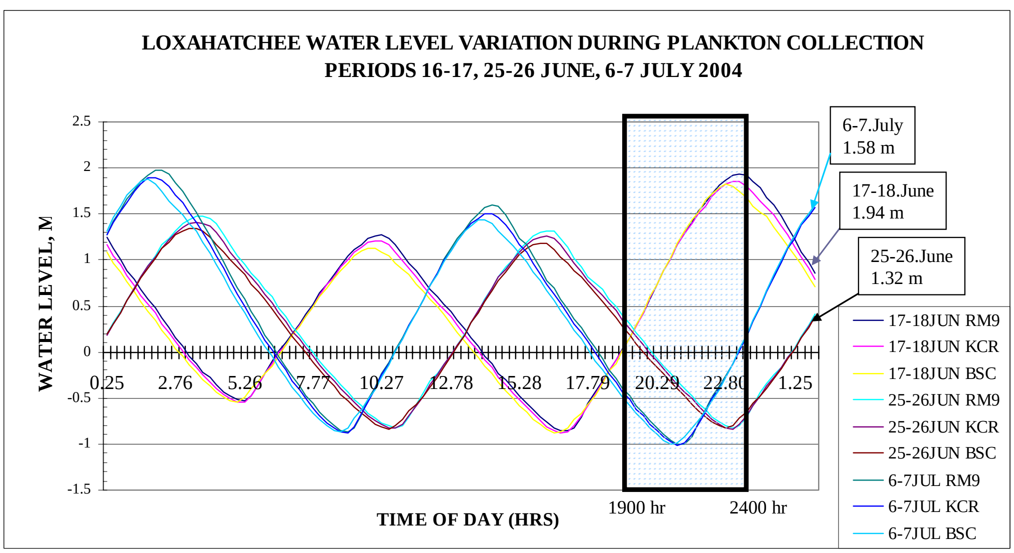
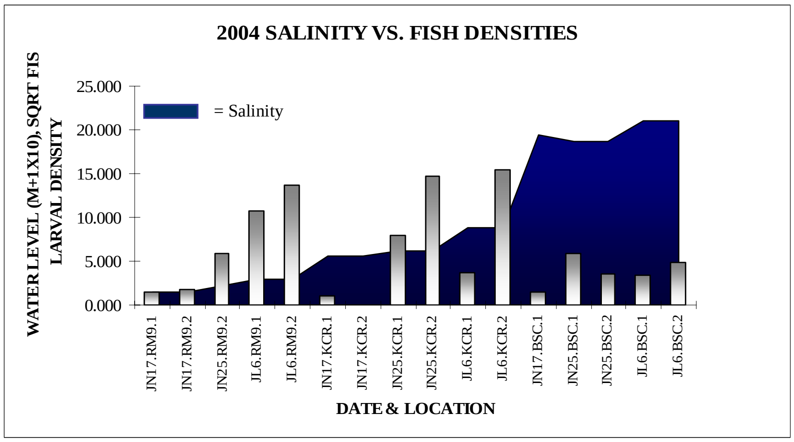


Figure H-7. Water Level Fluctuation Before and During Zooplankton Sampling 17-25 June and 6 July 2004 Taken From All USGS Stations Between RM 6 and RM 9.

Figure H-8 represents a cluster from a similarity analysis using salinity and water level values from all stations. It reveals a closer similarity between stations upstream of RM 8, though the high water collections made on 17 June still show some differentiation. RM 7 shows the greatest distinction from upstream stations using these physical factors. Zooplankton clusters follow a similar pattern.



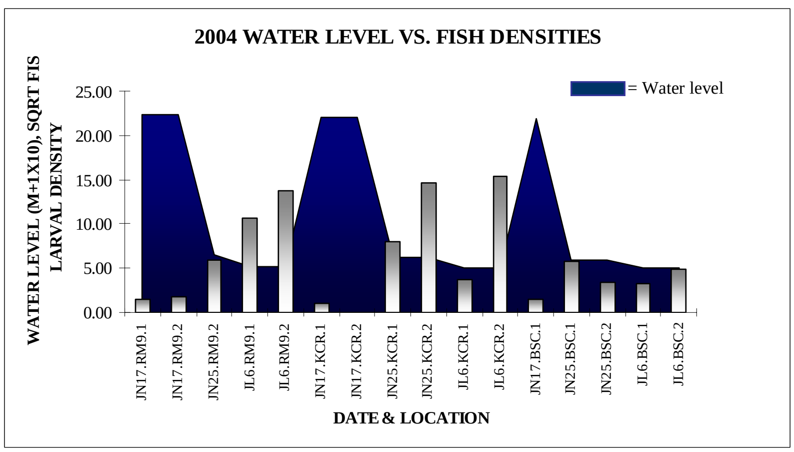


Figure H-8. Mean Fish Density for All 2004 Stations Relative to Water Level (in Meters +1 $\times$10) and Salinity (ppt).

1986-1988 Water Level Effects: Historical 1986-1988 data from the Loxahatchee River was examined for water level effects. It was anticipated that water level influence would be identical at both Stations 25 and 28 while salinities would differ between the two. A comparison of ichthyoplankton collections reveals a much greater densities of fish larvae at Station 28, than at Station 25, particularly during the dry season, February to July 1987 (**Figure H-9**). As water level fluctuations were not that dissimilar between the two locations it would appear that salinity would have a greater effect. However, at both locations the lowest fish larvae captures occurred during the highest water levels, fall both in 1986 and 1987. This reveals a seasonal water level effect. An unusual dry season peak in water level, March 1987, still revealed high fish larval abundance. This occurrence has implications on water level influence which may be different from that observed in the 2004 work. Reasons for this will be discussed with some comparative documentation in the Results and Discussion section.

A PCA analysis of 1986-1988 fish larval data from Stations 25 and 28 relative to water levels and salinities at both stations reveals close overlap in water level values for both stations and a wide salinity separation with the Station 28 salinity revealing the greatest affinity to the fish larval abundance pattern. The salinity at Station 25 was most divergent from all the other parameters. This implicates salinity as a major factor influencing fish larval abundance.

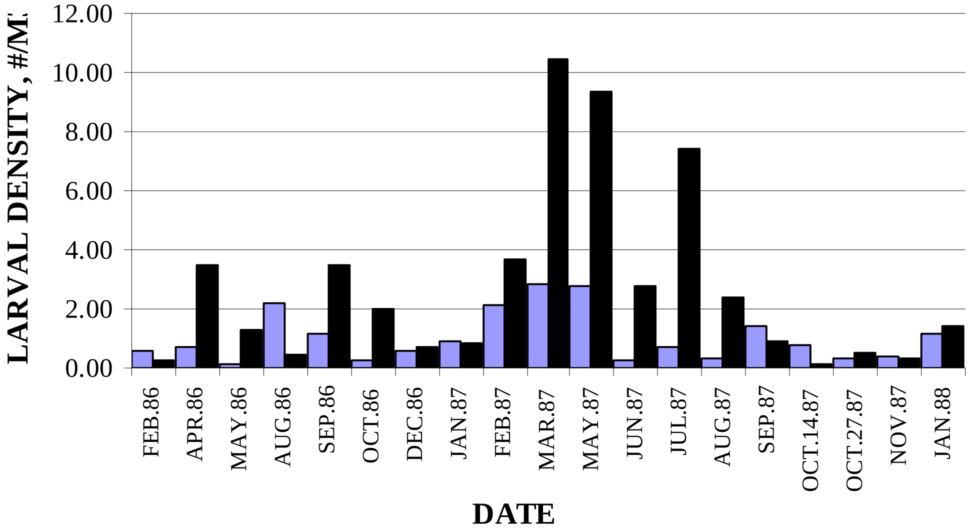


Figure H-9. Comparison of Spatial Variation in Larval Densities from Station 25 (Blue) and Station 28 (Black), 1986-1988.

2004 Salinity Effects: USGS salinity data were analyzed for a 3-month period, 1 June to 31 August 2004 from gauging stations at RM 6, RM 8 and RM 9. The major change in salinity from greater than 15 ppt to less than 10 ppt occurs between RM 6 and RM 8; RM 8 is at the mouth of Kitching Creek. From RM 8 to RM 9 the salinity consistently stays below 5 ppt even during this drought period. The passage of Hurricane Charlie is apparent in August pushing RM 6 post-hurricane salinities to salinities similar to those at RM 8 observed during the drought period. This is significant in that most June and early July larval fish were captured at salinities between 2 ppt and 8 ppt between RM 8 and RM 9.

Figure H-10 presents larval fish and crustacean abundance relative to salinity and collection station in 2004. Two patterns are apparent: 1) both crustacean and fish numbers decline between Stations 5/6 and Stations7/8; 2) larval fish and crustaceans are most abundant at Stations 5/6, fish from 3 to 6, where salinities ranged from 2 ppt to 8 ppt. **Figure H-11** presents the fish and crustacean data converted as square root number of individuals, showing both fish and crustacean numbers decline considerably at RM 7, Stations 7/8 where salinities exceed 12 ppt.

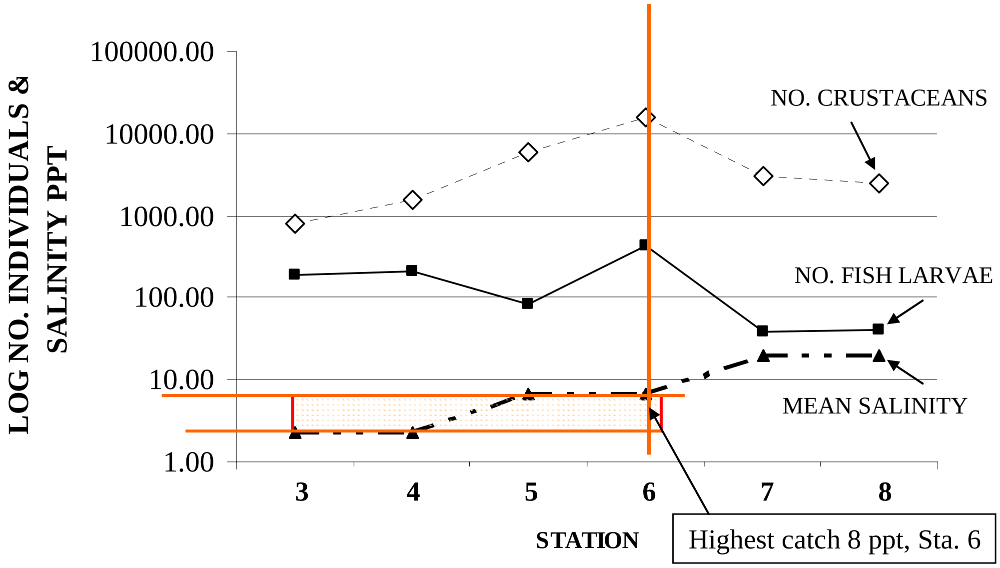


Figure H-10. Larval Fish (sq. root number of individuals) and Salinity for All 2004 Collections Downstream of Stations 1 and 2. Orange Box Surrounds Salinity Region of Greatest Fish Larvae Abundance.

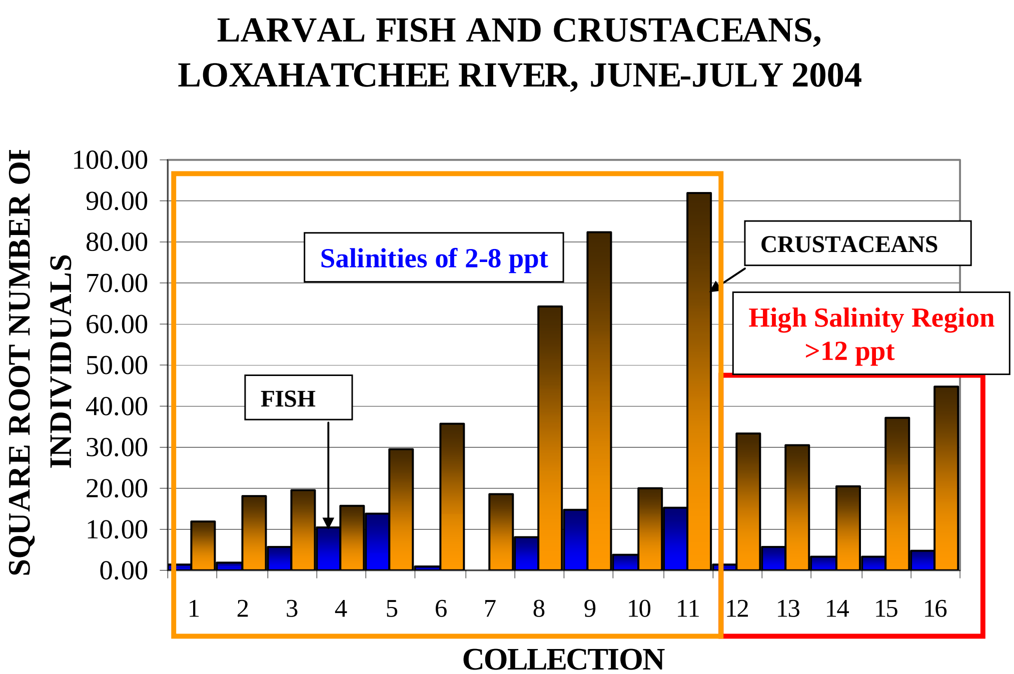


Figure H-11. Larval Fish and Crustacean Abundance from Upstream Collections 1-5 to Downstream Collection 12-16 Revealing Differential Spatial Distribution June-July 2004.

1986-1988 Data: Spatial and Temporal Distribution: Differential Effect of Water Level and Salinity: The 1986-1988 data allows considerable perspective on temporal distribution of both physical and biological parameters. Multiannual, seasonal and monthly patterns in water level and salinity are apparent (**Figures H-12** and **H-13**). The 2 ppt to 8 ppt salinity window that coincided with the greatest zooplankton abundance in the 2004 study is marked by a yellow line in **Figures H-12** and **H-13**. At Station 28, (RM 7), the general periods when salinities are within the 2-8 ppt range are January-April both in 1986 and 1987 with June and August hovering around 2 ppt. When compared to Station 25 further toward the estuary (**Figure H-13**), the only periods when salinities enter the 2-8 ppt window are in June, August and October. The remainder of the year they are above 8 ppt, typically between 10 and 20 ppt at this location. The typical regional highest water levels associated with high rainfall, river flow and annual sea level rise is observed in the fall in both Stations 25 and 28. However, 1987 appears to be a drier summer-fall year with salinities remaining high in spite of a water level increase. This means during 1987 the freshwater flow component of annual sea level rise (of the three major components, rainfall and freshwater runoff, onshore easterly winds and North Atlantic Ocean basin expansion due to warming) was not very large. Low 1986 summer-fall and winter salinities and freshwater flows in the Loxahatchee River during this period reduced salinities from June 1986 to March 1987. The atypical rise in water level in March 1987 associated with a low salinity at Station 28 must be due either anomalous rainfall at this time or freshwater release from water control structures.

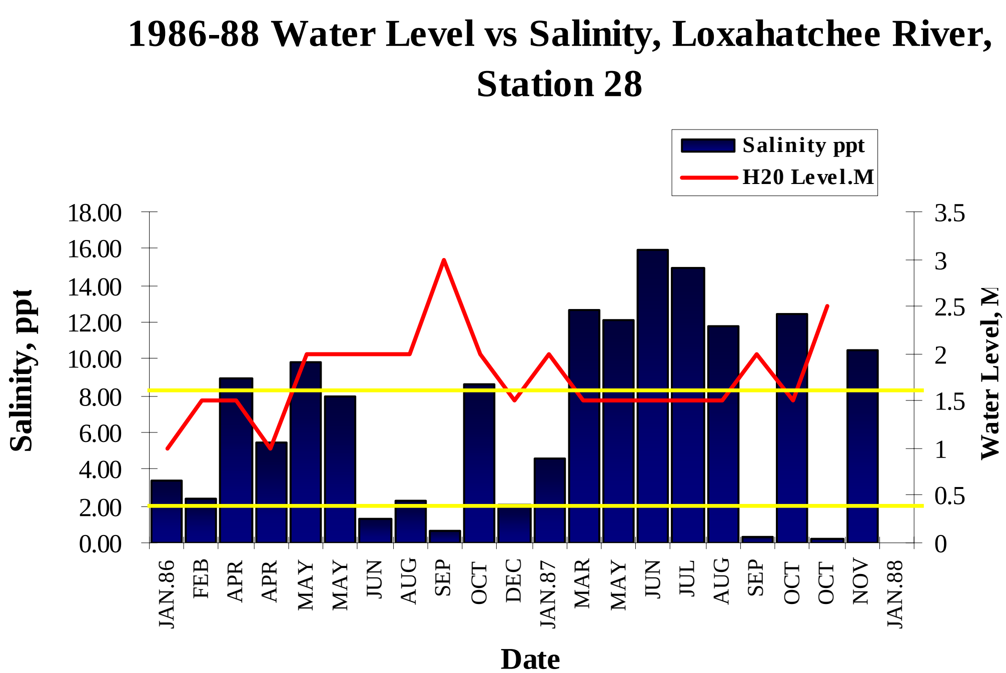


Figure H-12. Water Level and Salinity, Station 28, 1986-1988. Yellow Lines Demark the 2-8 ppt Salinity Preference Observed for Goby Larvae in 2004 and 1986-1988 Data.

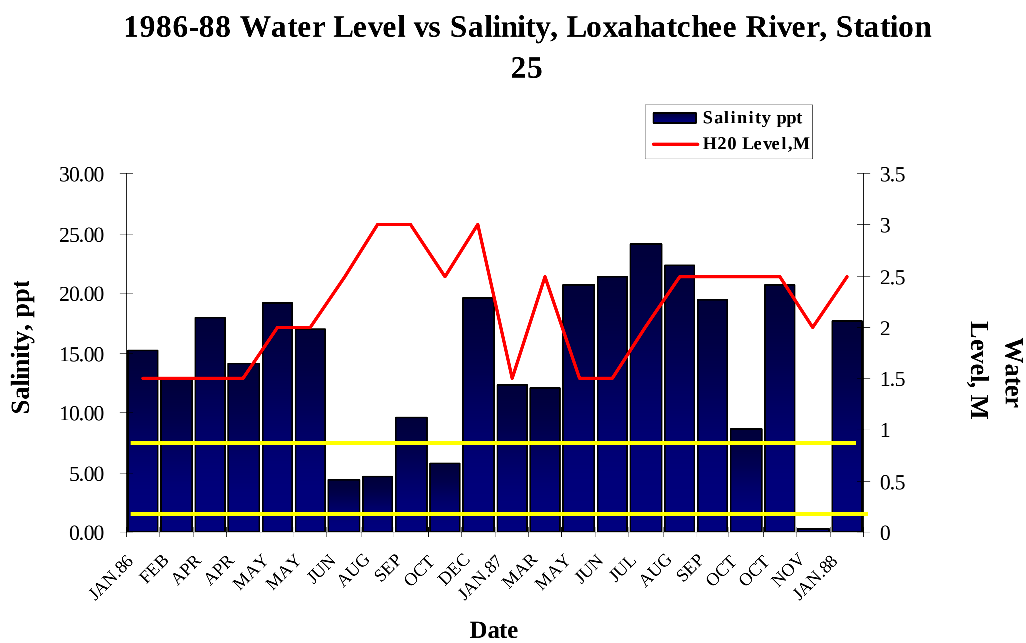


Figure H-13. Water Level and Salinity, Station 25, 1986-1988. Yellow Lines Demark the 2-8 ppt Salinity Preference Observed for Goby Larvae in 2004 and 1986-1988 Data.

Fish larval densities are plotted with the salinities in **Figure H-14**, again with the 2-8 ppt salinity box depicted. Fish densities associated with salinities within the 2-8 ppt range are noted with orange boxes. These periods also mark the time of the highest concentration of fish larvae at Station 28 during the 2-year period. The third highest larval count was taken in July 1987 at salinities above 14 ppt. However, this is the period of the year with the lowest water levels, thus the potential to concentrate larvae, or move larvae downstream from exposed and reduced upstream habitats. Since the majority of the typical wet season in 1987 shows high salinities at Station 28, it is likely that drought conditions were occurring late spring to fall. This would produce low flows, low water levels and higher than average salinities. The result would be little optimum salinity occurrence, 2-8 ppt at Station 28 and few fish larvae. This was the case September 1987 through January 1988.

Fish larval collections were considerably lower at Station 25 than those at Station 28. The ambient salinity pattern at Station 25 is high relative to Station 28 and only showed the optimum 2-8 ppt window June through October 1986. This was the period when most fish larvae were captured in 1986. Numbers of larvae were also captured February through May in 1987 when salinities dropped from 20 ppt to between 10-15 ppt and water levels fell.

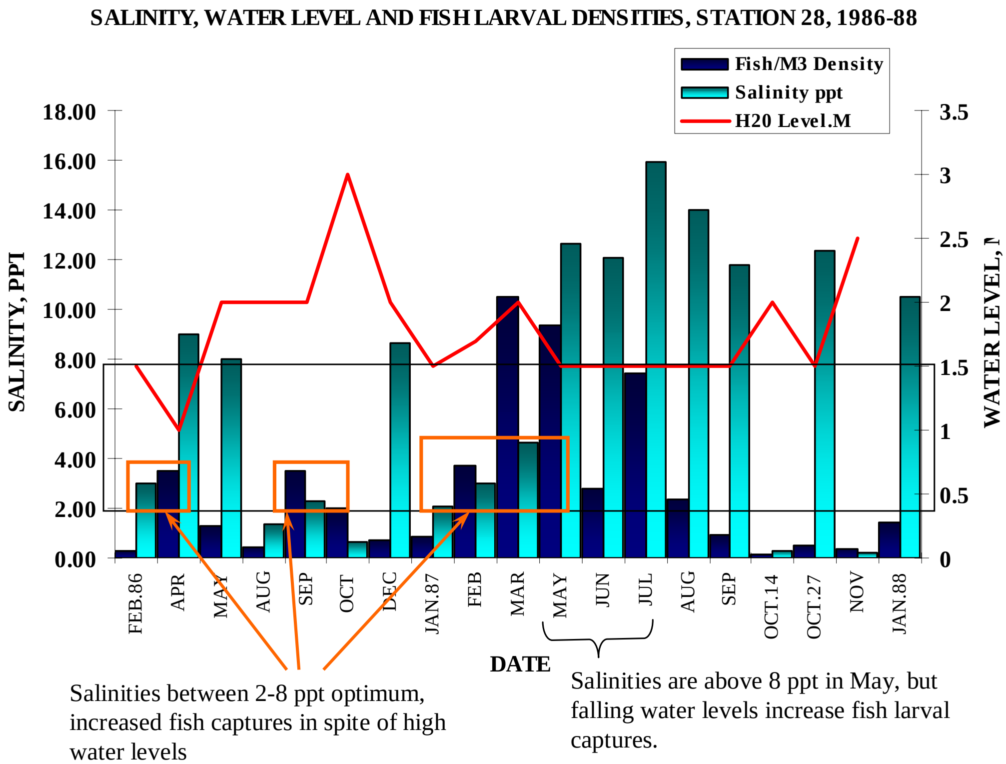


Figure H-14. Plot of Fish Larval Densities from 1986-1988 with Water Level and Salinity for Station 28 Only. Salinity Larval Density Periods of Interest Are Noted.

When salinity for every month at Station 28 is used to produce a similarity matrix and clustered with Bray Curtis group average similarity analysis (**Figure H-15**) the periods of salinity dry and wet seasons are apparent. The highest regional rainfall typically occurs in September to October, Group TW in **Figure H-15** shows this pattern with salinities below 1.0 ppt. The TD group is a dry season group with salinities typically above 8 ppt. The optimum group for fish larvae is the AW group with salinities below 6 ppt, which did in fact have the largest fish larval captures. The same analysis using both Station 25 and Station 28 data reveals a similar cluster in **Figure H-16.**

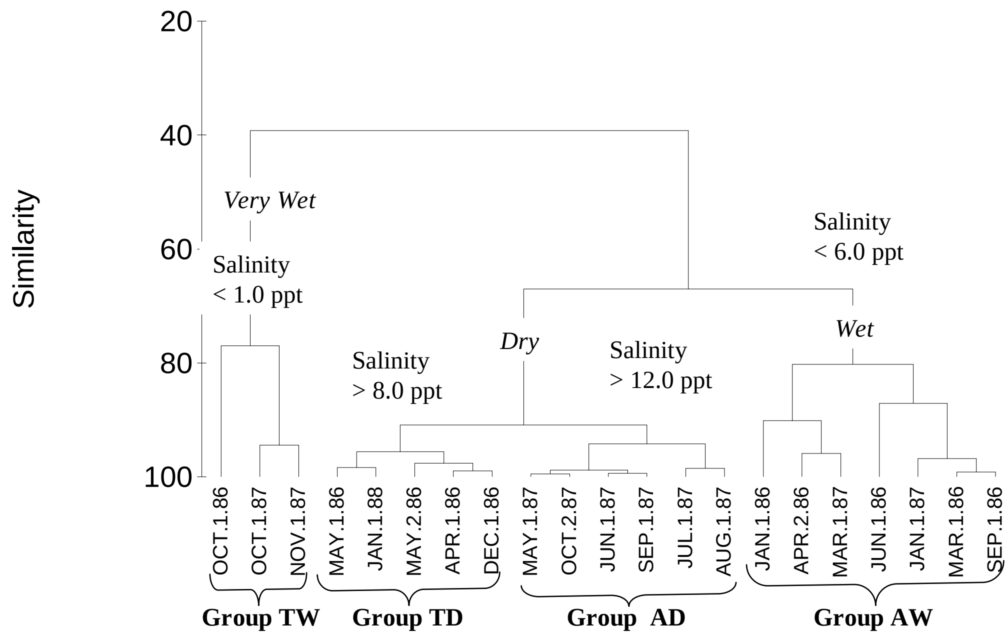


Figure H-15. Cluster Based on a Group Average Similarity Analysis Using Mean Daily Salinity for Station 28, 1986-January 1988. Salinity for Date of Zooplankton Capture.

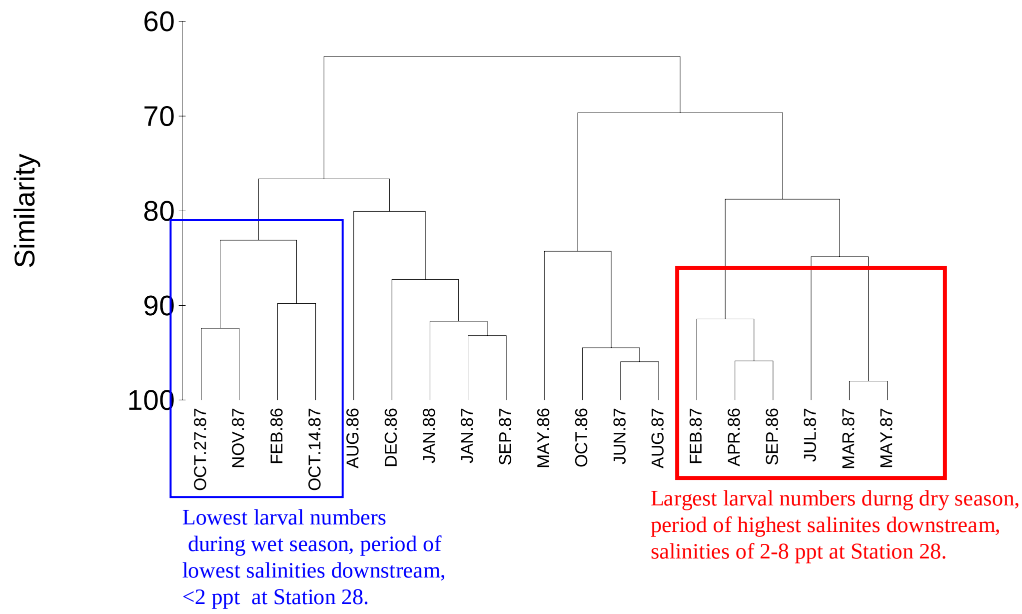


Figure H-16. Similarity Analysis Bray-Curtis Group Average Cluster Plot Based on Fish Larval Density from Station 25 and Station 28, 1986-1988.

Results and Discussion

The optimum natural condition in which to examine the influence of freshwater flow on a riverine fauna is to examine the fauna at the lowest possible flow condition over a broad enough range of salinity within the shortest spatial and temporal (diel) range practical. This would insure temporal continuity between samples, therefore limiting potential impacts from factors that change rapidly during a sampling period, such as water levels and tidal action. Appropriate replication and adequate ancillary data should be acquired. We attempted to include all these considerations in this analysis of dry season larval fish recruitment, zooplankton abundance in the protected portion of the Loxahatchee River during the late spring and early summer 2004. We tested two null hypotheses: 1) “$H^o{}_1$ No particular taxon consistently numerically dominates the larval fish communities indigenous to the Loxahatchee River”; and 2) “$H^o{}_2$ Fish larval abundance is evenly distributed between RM 6 and RM 10 in the main course of the river during the “dry season” low rainfall, low flow periods, winter to late spring/early summer (December to July).”

“$H^o{}_1$" Loxahatchee River Larval Fish Community Defined: Our results demonstrated that a diverse yet predictable larval fish community occurs within the Loxahatchee River and is consistently numerically dominated by three to four fish families. This fauna consists primarily of gobies (gobioids), anchovies (engraulids), pipefishes (syngnathids) and silversides (atherinids) during the dry season. These same taxa numerically dominated samples taken at Station 28 in 1986 to 1988 and in 2004 revealing a long term consistency in fish larval community structure within the Loxahatchee River.

Station 25 collected from 1986 to 1988 was located below RM 6.0 at RM 5.3. Salinities at this location ranged between 1 ppt and 24 ppt, most often between 10 ppt and 20 ppt. The ichthyofauna was richer at Station 25 and revealed a higher diversity at the family level (**Figure H-17**). Gobioids, the most abundant fish larvae in the Loxahatchee River, are known to occur in the freshwater tributaries to the Indian River Lagoon including the Loxahatchee River are listed in **Table H-1**. The relative numerical abundance of various gobioid species is presented from data recently published by Paperno and Brodie (2004).

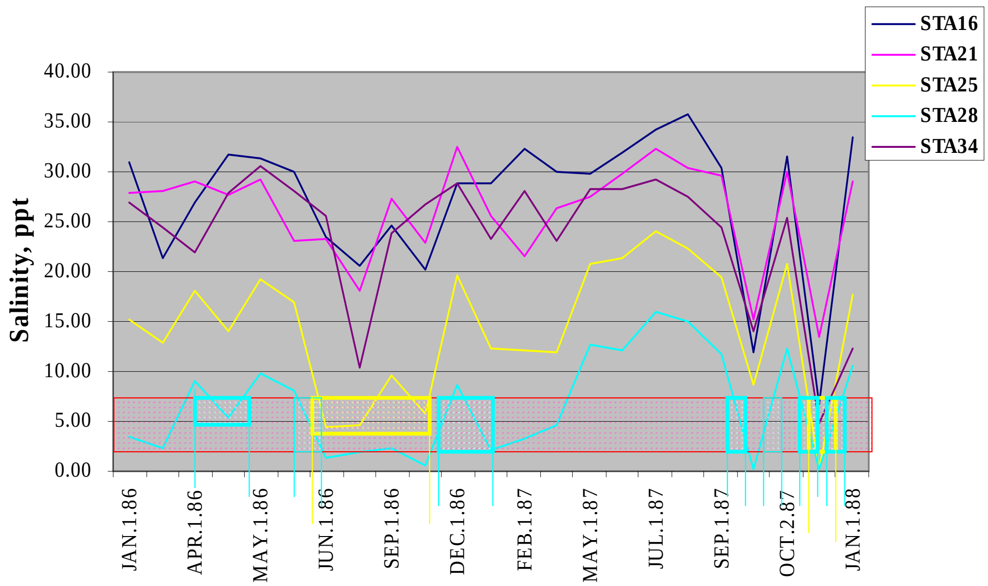


Figure H-17. 1986-1988 Mean 24-Hour Salinity for Date of Zooplankton Capture, Stations 16 through 34 in the Loxahatchee River and Estuary. Periods of Optimum Salinity for Fish Larval Capture Is Indicated with the Red Band, Within Which Optimum Station Captures for Station 25 (Yellow) and Station 28 (Blue) are Boxed, Based on 2004 Capture Data.

Table H-1. Gobioid Species of the Loxahatchee River.

	Taxa	Larval Capture	Abundance No. Individuals (% Occurrence)	Spawning Migration Tendency
Eleotridae				
1	*Gobiomorus dormitor*	?	114 (18)	Freshwater Semi-catadromous
2	*Dormitator maculatus*	X	374 (21.1)	Freshwater Semi-catadromous
3	*Eleotris amplyopsis*	?		Freshwater Semi-catadromous
Gobiidae				
4	*Awaous banana*	?		Freshwater Semi-catadromous
5	*Bathygobius soporator*	?		Estuarine, non migratory
6	*Ctenogobius pseudofasciatus*	?	14 (3.9)	Freshwater Semi-catadromous
7	*Ctenogobius fasciatus*	?		Freshwater Semi-catadromous
8	*Ctenogobius schufeldti*	?	11 (5.5)	Freshwater
9	*Gobioides brousonettii*	X		Freshwater Semi-catadromous
10	*Gobionellus oceanicus*	?		Estuarine, non migratory
11	*Gobiosoma bosc*	X	165 (15.6)	Estuarine, non migratory
12	*Gobiosoma robustum*	X		Estuarine, non migratory
13	*Gobiosoma macrodon*	?		Estuarine, non migratory
14	*Lophogobius cyprinoides*	?	134 (25.8)	Estuarine, non migratory
15	*Evorthodus lyricus*	X	464 (27.3)	Freshwater Semi-catadromous
16	*Microgobius gulosus*	X	123 (23.4)	Estuarine, non migratory

Data from Paperno and Brodie, 2004.

Tropical marine invaders, the Diadromus Domination: The warm Florida Current flows along the lower east coast of the Florida producing a subtropical-tropical coastal oceanographic and climatic/hydrological setting for the Loxahatchee River. A typical tropical coastal climate pattern occurs in the region of the Loxahatchee River (Christensen 1965; Gilmore 1977a,b, 1985; Gilmore and Hastings 1983). A distinct wet season with natural high riverine flow rates occurs during the summer and fall, followed by a dry season low flow high salinity period starting in the late fall extending though the winter and spring (Gilmore 1977; Gilmore and Hastings 1983). This pattern differs significantly from the seasonal freshwater flow periodicity in other southeastern tributaries of the Piedmont coastal plane north of 28° 30' N (Rogers et al. 1984; Peterson and Meador 1994). Climatic and biological conditions in these regions, as well as Gulf coastal Florida, are not representative of southeast Florida tributaries and coastal estuaries (Gilmore et al. 1978; Rakocinski et al. 1992; Gilmore 2001; Streams of Florida). This is largely due to differences in the geomorphology of the Florida peninsula and proximity of warm tropical ocean currents. Most other Florida stream systems on the upper Gulf coast and north of Cape Canaveral, Florida show high stream flows during the fall through winter/spring, and often have drier summers (Rogers et al. 1984; Peterson and Meador 1994). These differences in seasonal flow patterns has some influence on aquatic organism spawning periodicity and larval recruitment as well as levels of primary and secondary productivity, with tropical systems differing significantly from warm temperate systems.

A local geological and geographic setting of the southern Indian River Lagoon and its freshwater tributaries has produced high biodiversity in local aquatic ecosystems. The climatic and ocean frontal boundaries between 26° and 29° N Longitude creates a biogeographic transition zone with significant overlap in tropical and temperate biological elements. Various portions of each biological community are numerically dominated by either warm temperate, temperate or tropical species. Historical documentation of biotas within Jupiter Inlet, Hobe Sound and the Loxahatchee River region revealed a biota that is largely numerically dominated by tropical and warm temperate species (Christensen 1965; Gilmore 1977a,b, 1995). Recent numerical studies of a neighboring small coastal stream system, the St. Sebastian River, produced similar results (Paperno and Brodie 2004).

The dominance of gobioid larvae is typical of tropical estuaries throughout the world. Where gobies have adapted to temperate estuaries they numerically dominate the ichthyoplankton (Shenker et al. 1983). The gobioid fishes can also numerically dominate open ocean ichthyoplankton (Richards 1984; Ahlstrom 1971, 1972; Nellen 1973). This fish family has the most species occurring to ocean depths of 1,500 feet (Gilmore, personal observation) as well as inhabiting freshwater streams and anoxic mangrove forest habitats. They are also the richest fish faunal element in the Loxahatchee River with at least 16 species occurring in this small coastal stream system.

The anchovies, engraulidae, are next in abundance possibly including both tropical and temperate species. They are typically the most numerically abundant marine and coastal estuarine fish as adults. This may be why engraulid larvae numerically dominated ichthyoplankton captures at Station 25, but not at Station 28 during 1986-1988.

Other marine and estuarine species that were common, or occurred, in both historical samples, 1986-1988, and in the 2004 samples, were larval mojarras (gerreidae), drums and croaker (sciaenidae), herrings/sardines/menhaden (clupeidae), silversides (atherinidae), and pipefishes (syngnathidae). The historical collections also included some larval blennies (blennidae), and various flatfishes (soleidae, bothidae and cynoglossidae). These are families which are commonly represented in the ichthyoplankton of tropical freshwater tributaries elsewhere in the world (Blaber 2000).

Noticeably absent were larval snook (centropomids). There are five species of snook in the Loxahatchee River, the common snook, *Centropomus undecimalis*, largescale fat snook, *C parallelus*, smallscale fat snook, *C. mexicanus*, tarpon snook, *C. pectinatus* and the swordspine snook, *C. ensiferus*. All of these species have been captured as juveniles and adults in the Loxahatchee, St. Lucie and St. Sebastian Rivers. No other stream or river system in Florida has all of these species recorded from it. However, larvae of any species of centropomid were absent from all the historical samples and the 2004 samples. Nevertheless, snook eggs and larvae were abundant in a sample made within Jupiter Inlet on 2 July 2004 indicating that snook were spawning at that time. The eggs and larvae must be carried into habitats which were not sampled.

Larvae of primary freshwater fishes, centrarchids, cyprinids, percids, and catostomids, were also absent from in the 2004 samples. Centrarchids and cyprinids were listed as having been taken in the 1986-1988 samples at Station 28, but did not form a large portion of the larval collections. The primary freshwater fish fauna of the southern Florida peninsula is depauperate relative to northern Florida. Freshwater faunas of the southern peninsula are numerically dominated by euryhaline secondary freshwater families, anguillidae, cyprinodonts, poeciliids and atherinids and many marine invaders particularly in coastal streams. Euryhaline marine/estuarine invaders are present either as juveniles and adults, but not necessarily as larvae. These include bull sharks, ladyfish, tarpon, ariid catfishes, and mullets, snooks, centropomidae, mangrove snapper, burro grunt, sheepshead porgy, sciaenids, cichlids and various flatfishes, bothids, cynoglossids and soleids. Soleid larvae were represented in our 2004 samples. These families and the general invasion of freshwater by adults and juveniles of marine and estuarine phyla is a worldwide tropical phenomenon (Blaber 2000). Spawning is another matter. Very few marine fishes in these families place their eggs and larvae into low salinity waters. Nearly all spawn in the ocean and their larvae require higher salinities to survive. The marine fish families, gobiids, synganthids and engraulids are the top euryhaline spawners.

Tropical island and coastal continental freshwater stream faunas are often numerically dominated by marine and estuarine species that may enter freshwater for extended periods of time. They often depend on freshwater to complete vital developmental or reproductive periods. Diadromy is a common life history strategy for these species (McDowall 1988). The numerical dominance of tropical marine and estuarine species in freshwater habitats is typical of many coastal settings in the tropical Americas and Caribbean islands (Blaber 2000).

“H^{o}_{2}" *Fish Larval Dynamics Relative to Salinity and Water Depth*: The dynamics of the Loxahatchee river ichthyoplankton community was examined relative to collection sites, salinity, and water level using the 2004 and in the historical 1986-1988 collections . Additional parameters evaluated for the 2004 collections included temperature, dissolved oxygen and water flow rates but since these parameters did not vary significantly between stations during the recent ichthyoplankton survey it appears that salinity is the major factor responsible in influencing densities. However, the major portion of the ichthyofauna was captured at the confluence of the Kitching Creek and the main course of the Loxahatchee River. This could also be a site of nutrient flow, organic materials and consequently, primary productivity which would then produce a microzooplankton bloom of copepods and ostracods that were not captured with the net we used. This microzooplankton bloom would then feed larger invertebrate plankton and fish larvae. Nutrients and organic material concentrations were not examined so the influence of these parameters on fish larval distribution could not be determined. It is also possible that the large low tide captures on an ebbing tide, 25 June and 6 July 2004 could be due to the fact that even though the fish and invertebrate larvae typically migrate to the surface at night, they might not do so on an ebbing tide as they may be carried out into the adjacent estuary. In order to maintain an upstream position they would migrate to the river bottom. The 0.5-m plankton net may have sampled this bottom habitat in upstream waters between RM 8 and RM 9 while the water depth was too great to sample the bottom habitat at Stations 7 and 8 at RM 7. This would produce higher larval densities upstream simply as a sampling artifact. However, the high tide collection made on 17 June also captured more invertebrates between RM 8 and RM 9 than at RM 7, indicating the 2-8 ppt salinity region and its high ichthyoplankton density was likely not a sampling artifact.

The 1986-1988 collections were always made on a flood or high tide yet revealed the same fish larvae species ranking based on numerical abundance with most larvae captured when salinities were between 2 and 8 ppt for both Stations 28 and 25 **(Figure H-17)** with the greatest abundance at Station 28 at RM 7. Where this salinity range (2 to 8 ppt) occurred, the greatest concentration of fish larvae also occurred in 2004 between RM 8 and RM 9 (**Figure H-18)**, with most larvae being captured in the vicinity of the mouth of Kitching Creek at RM 8. The highest density of fish larvae captured in the Pautuxent River (Shenker et al. 1984) were captured between salinities of 2-3 ppt. Similar salinity association patterns were observed in the San Francisco Estuary (Dege and Brown 2004). Apparently, fish larvae concentrate in the Low Salinity Zone of estuarine systems, however, since each system has unique characteristics, field investigations need to document this important low salinity range for each estuary. Thus, the 2 ppt to 8 ppt range, under low flow conditions in the Loxahatchee River, is unique to this estuary. The most downstream location of this salinity range we documented from the historical data is near RM 7. Hence, we cannot show the natural concentration of fish larvae will occur further downstream than RM 7 with increased base flows due to changes in hydrodynamics with increased flows. Increased base flows will reduce the particle residence time within the appropriate salinity range and may affect the formation of a turbidity maximum. Further, as this range progresses downstream the physical attributes of the estuary (i.e., bathymetry, water surface area) will change hydrodynamic conditions possibly needed to facilitate increased zooplankton concentrations in the turbidity maximum. Significant physical changes occur downstream of RM 6. For example, the surface area of water and length of shoreline from RM 7 to RM 6 is 30.7 acres and 92,835 ft in contrast to one mile downstream (RM 6 to RM 5) has 88.8 acres and 152,045 ft of shoreline, respectively (**Chapter 3**; **Table 3-5**). Additionally, the impact of human influences such as lighting and hardening shorelines which cause the loss of shallow shoreline transitional habitat, increases significantly downstream of RM 6 and has unknown affects on fish larvae recruitment.

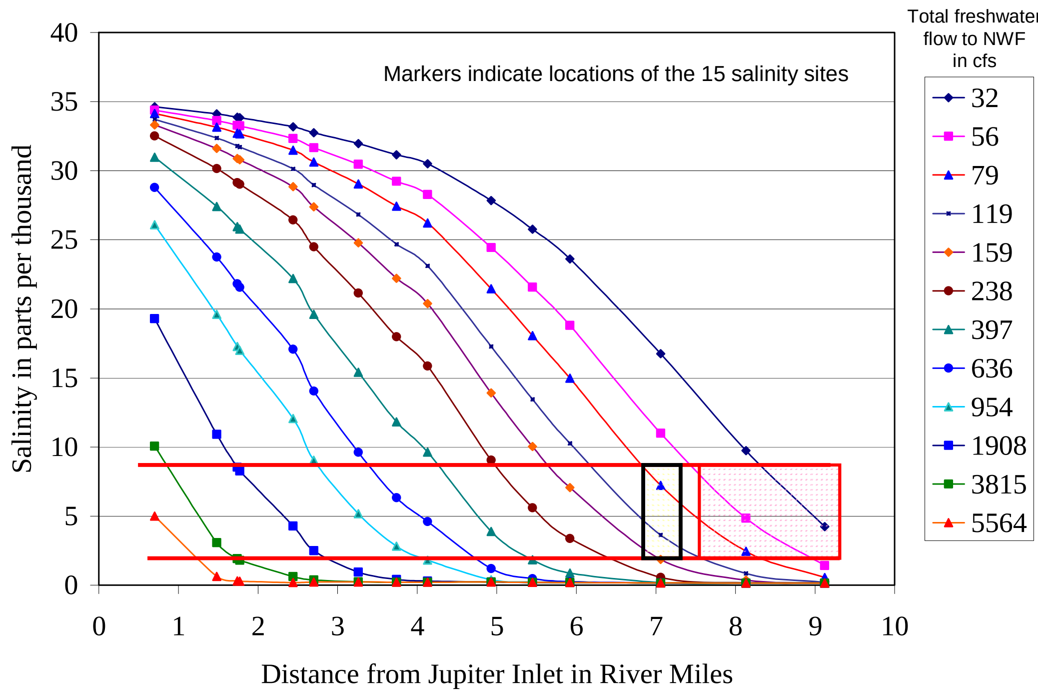


Figure H-18. Red Rectangle Represents Location and Salinity at Which Largest Zooplankton Captures Were Made in June-July 2004, Yellow Rectangle, 1986-1988.

Since these important changes in the estuary occur downstream of RM 6, the preferred salinity range should not extend beyond this location during the dry season when it is most important to fish larvae. **Figure H-18** shows a base flow near 140 cfs (Scenario **LD65TB65**) provides a salinity of 2 ppt at RM 7.2 and 8 ppt at RM 6. To corroborate these findings, daily salinities for all scenarios at RM 5.92 were examined and the same conclusion was established. Therefore, scenario **LD65TB65** is the maximum flow recommended to avoid significant alteration of conditions favorable to fish larvae in the estuarine area of the Northwest Fork of the Loxahatchee River.

LITERATURE CITED

Ahlstrom. 1971.

Ahlstrom. 1972.

Blaber, S.J.M. 2000. *Tropical estuarine fishes: Ecology, exploitation and conservation*. Blackwell Science, Oxford, UK.

Christensen, R.F. 1965. An ichthyological survey of Jupiter Inlet and Loxahatchee River. MS thesis, Florida State University, Tallahassee, FL. 318 pp.

Dege, M. and L.R. Brown. 2004. Effect of outflow on spring and summertime distribution and abundance of larval and juvenile fishes in the upper San Francisco estuary, In *Early life history of fishes in the San Francisco Estuary and Watershed*, ed. F. Feyrer, L.R. Brown, R.L. Brown and J.J. Orsi. American Fish Society Symposium. 39.

Gilmore, R.G. 1977a. Notes on the opossum pipefish, *Oostethus lineatus* from the Indian River lagoon and vicinity, Florida. *Copeia,* 1977:781-783.

Gilmore, R.G. 1977b. Fishes of the Indian River Lagoon and adjacent waters, Florida. *Bulletin Florida State Museum, Biological Science*, 22(3):101-148.

Gilmore, R.G. 1984. *Fish and macrocrustacean population dynamics in a tidally influnced impounded subtropical salt marsh*. Final Report. Florida Department of Environmental Regulation – Coastal Zone Management Contract No. 47/73. 35 pp., 20 tables, 31 figures.

Gilmore, R.G. 1995. Environmental and biogeographic factors influencing ichthyofaunal diversity: Indian River Lagoon. *Bulletin of Marine Science,* 57:153-170.

Gilmore, R.G. 2001. The evolution of the Florida fish fauna. *Proceedings of the Bulletin of the Gulf and Caribbean Fisheries Institute*.

Gilmore, R.G. and P.A. Hastings. 1983. Observations on the ecology and distribution of certain tropical peripheral fishes in Florida. *Florida Scientist*, 46:31-51.

Gilmore et al. 1978.

Hastings. 1979.

Houde, E.D. 1994. Differences between marine and freshwater fish larvae: Implications for recruitment. *ICES Journal of Marine Science,* 51:91-97.

McDowall, R.M. 1988. *Diadromy in fishes*. Timber Press, Portland, OR. 308 pp.

Nellen 1973.

Paperno, R. and R.B. Brodie. 2004. Effects of environmental variables upon the spatial and temporal structure of a fish community in a small, freshwater tributary of the Indian River Lagoon, Florida. *Estuarine Coastal Shelf Science*, 61:229-241.

Peterson, M.S. and M.R. Meador. 1994. Effects of salinity on freshwater fishes in coastal plain drainages in the Southeastern U.S. *Review of Fisheries Science*, 2(2):95-121.

Rakocinski, C.F., D.M. Baltz and J.W. Fleeger. 1992. Correspondence between environmental gradients and the community structure of marsh-edge fishes in a Louisiana estuary. *Marine Ecology Program Series,* 80:135-148.

Richards, W.J. 1984. *Kinds and abundances of fish larvae in the Caribbean Sea and adjacent areas*. NOAA, Technical Report NMFS-SSRF-776. 54 pp.

Rogers, S.G, T.E. Targett and S.B. Van Sant. 1984. Fish-nursery use in Georgia salt-marsh estuaries: The influence of springtime freshwater conditions. *Transactions of the American Fisheries Society,* 113:595-606.

Shenker, J.M., D.J. Hepner, P.E. Frere, L.E. Currence and W.W. Wakefield. 1983. Upriver migration and abundance of naked goby (*Gobiosoma bosci*) larvae in the Patuxent River estuary, Maryland. *Estuaries,* 6:35-42.

Shenker et al. 1984.

Streams of Florida.